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WORK PLAN FOR SITE INVESTIGATION FOR DISEASE VESTOR ECOLOGY AND
CONTROL CENTER NAS JACKSONVILLE FL
12/1/1996
TETRA TECH

Work Plan

FILE

for

**Site Investigation for
Disease Vector Ecology and
Control Center**

Naval Air Station
Jacksonville, Florida



**Southern Division
Naval Facilities Engineering Command**

Contract Number N62467-94-D-0888

Contract Task Order 0014

December 1996

WORK PLAN
FOR
SITE INVESTIGATION FOR
DISEASE VECTOR ECOLOGY AND CONTROL CENTER
NAVAL AIR STATION
JACKSONVILLE, FLORIDA
COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
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Naval Facilities Engineering Command
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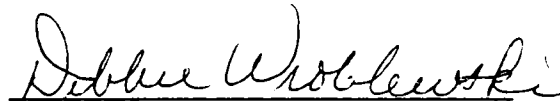
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1.0 INTRODUCTION

Brown & Root Environmental (B&R Environmental) prepared this Site Investigation Work Plan for the Navy Disease Vector Ecology and Control Center (DVECC) underground tank, ancillary drains, and sink room at Building 937 (the DVECC Building 937 Site) at Naval Air Station Jacksonville, Florida (NAS JAX). This task is authorized by the U.S. Navy (Navy) Southern Division Naval Facilities Engineering Command (SOUTHNAVFAC) under Contract Task Order (CTO) 0014, for the Comprehensive Long-term Environmental Action Navy (CLEAN III) Contract Number N62467-94-D-0888.

This Work Plan has been integrated with the Sampling and Analysis Plan (SAP) and describes the data collection efforts necessary to assess the vertical and horizontal extent of contaminants of concern in the subsurface at the referenced site. The data collected during the investigation will be used to prepare a Site Investigation Report and to support the RCRA closure of the DVECC Building 937 Site.

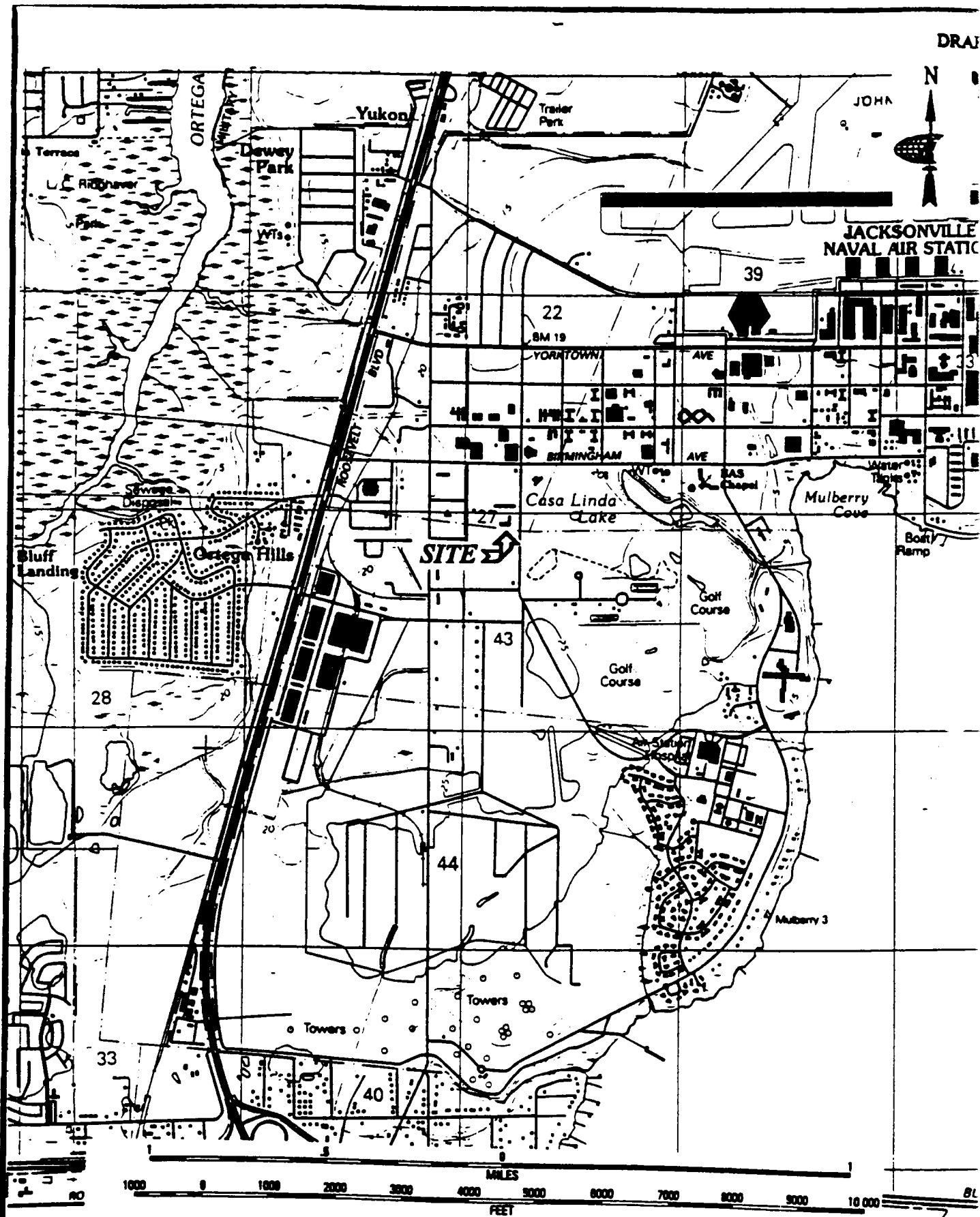
The Health and Safety Plan for this project is maintained under separate cover

1.1 GENERAL SITE DESCRIPTION

The DVECC Building 937 Site is located at Building 937 at NAS JAX within Duval County in Section 27, Township 3S, Range 26E. NAS JAX is bound by Roosevelt Boulevard on the west, the St. Johns River on the east, and residential areas to the south and north. The location of the DVECC Building 937 Site within NAS JAX is illustrated on Figure 1-1.

1.2 OBJECTIVE

The objective of the proposed investigation is to evaluate the extent of soil and or groundwater impacted with the compounds listed in Table T-1 of the October 24, 1995 NAS JAX letter to Florida Department of Environmental Protection (FDEP). A copy of the NAS JAX letter to the FDEP with attached Table T-1 is included in Appendix A of this Work Plan.



SITE MANAGER: WSP	CHECKED BY: -
DRAWN BY: TCB	DRAWING DATE:
SKETCHED BY:	SURVEY DATE:
SCALE: AS SHOWN	
CAT. NO.: 7380511	PROJ. NO.: 7383



Brown & Root Environmental

FIGURE 1.1
SITE LOCATION MAP
 NAS JAX DVECC
 JACKSONVILLE, FLORIDA

2.0 SITE DESCRIPTION

The DVECC Building 937 Site is located on Child Street immediately south of Pesticide Shop Building 536. The Base golf course is across Child Street to the east of the site. Recreational fields are located south and west of the site. DVECC has occupied Building 937 since 1978. For the period from 1978 to 1988 the DVECC Building 937 Site consisted of a mixing sink and associated piping located in the south end of Building 937, and a 1,000-gallon fiberglass underground storage tank (UST) and ancillary support areas used to collect and contain rinse water from the pesticide mixing equipment. The UST was located south of Building 937. The area surrounding Building 937 is mostly paved. The pesticides known to be used at the facility include DDT, Chlordane, Malathion, Baygon (propoxur), Diazinon, Dursban, and Dibrom.

2.1 SITE BACKGROUND

During October of 1995, the underground tank was removed by Bechtel Inc. (Bechtel). Rust Environment and Infrastructure Inc. (Rust) provided the oversight of the tank closure activities. The October 1995 Tank Closure Report, prepared by Rust, indicated that 33 drums of 55-gallon capacity and four rolloffs (no size reported) of waste soil, concrete, asphalt, drain piping, and the underground tank were removed from the site.

Laboratory analyses of soil and groundwater samples collected during the tank closure activities indicated the presence of chlorinated pesticides and chlorinated herbicides. A copy of the laboratory data from the October 1995 Tank Closure Report is available under separate cover.

The October 1995 Tank Closure Report indicates that the depth to groundwater at the site is approximately seven feet bls. However, no indication of groundwater flow direction is given and no data indicating the groundwater flow in the immediate area of the site is available. A very large scale groundwater flow map of NAS JAX is available but the map is of such a large scale that it is of limited value for site-specific use.

3.0 SITE INVESTIGATION

3.1 DATA QUALITY OBJECTIVES

SOUTHNAVFAC policy is to apply the data quality objectives (DQOs) decision making process to all data collection activities. The DQO process is a strategic planning approach developed by the U.S. Environmental Protection Agency (USEPA) (Guidance for the Data Quality Objectives Process, USEPA QA/G-4, 1994) that is based on the scientific method and is used to prepare for and implement data collection activities. The process provides a systematic procedure for defining the criteria that a data collection design should satisfy, including when to collect samples, and how many samples to collect.

The DQO process as applied to the NAS JAX DVECC site is relatively straightforward. The overall objective of this Site Investigation is to assess the soil and groundwater at the DVECC Building 937 Site to determine if the site meets the criteria for final RCRA closure.

The following four DQOs have been identified for the DVECC Building 937 Site and were used to develop this Work Plan:

DQO-1 Determine if soil and groundwater at the DVECC Building 937 Site meets the analytical criteria for final RCRA closure. The compounds of concern and the analytical criteria for closure are listed in Table T-1 of the October 24, 1995 NAS JAX letter to FDEP (Appendix A).

DQO-2 Determine the horizontal and vertical extent of soil and/or groundwater impacted by the compounds of concern through the installation of soil borings, groundwater monitoring wells, laboratory analyses of samples, and aquifer testing.

DQO-3 Test for the presence of the compounds of concern listed in Table T-1 (Appendix A) using the Method Detection Limits presented in Table 5.2 of the October 24, 1995 NAS JAX letter to FDEP (Appendix A).

DQO-4 Evaluate the results of the Site Investigation and make recommendations of options for obtaining RCRA closure of the site.

3.2 SITE INVESTIGATION TASK SUMMARY

As described in the DQOs, the primary goal of this Site Investigation is to determine the horizontal and vertical extent of any soil and or groundwater contamination exceeding RCRA closure requirements. A secondary goal is to present options for obtaining clean closure for the site if any soils or groundwater exceed RCRA closure criteria.

In order to accomplish the primary and secondary goals, the following tasks are planned:

- Field mobilization and demobilization coordination including a pre-investigation meeting with NAS JAX personnel;
- Drill five shallow (<15 feet deep) borings and one deep boring (<30 feet deep). Obtain continuous split-spoon samples from the deep boring to evaluate site lithology;
- Collect soil samples at one foot below land surface and one foot above the top of the water table from the six borings for the purpose of determining horizontal and vertical extent of impacted soils. Analyze soil samples using accelerated laboratory turn around time (TAT) for the compounds listed in Table T-1 (Appendix A);
- Convert each of the six borings into groundwater monitoring wells for the purpose of collecting ground water samples and determining groundwater flow direction. Analyze groundwater samples using accelerated laboratory TAT for the compounds in Table T-1(Appendix A);
- Install approximately eight additional soil borings based on the laboratory analyses of the soil samples from the first six borings to determine the extent of any impacted soils.
- Collect soil samples at one foot below land surface and one foot above the top of the water table from the eight borings for laboratory analyses for the compounds in Table T-1 (Appendix A);
- Perform two slug tests each on three of the six wells to determine aquifer characteristics;
- Survey the monitoring wells for horizontal and vertical location;
- Prepare a Site Investigation Report with recommendations for closure options, if warranted, incorporating those closure target levels listed in Table T-1 (Appendix A).

3.3 SITE INVESTIGATION TASK DETAILS

Subcontractor oversight and sample collection and shipping will be provided by B&R Environmental personnel. All applicable field forms are included in Appendix B. The following subsections detail the tasks proposed for completion of this project:

3.3.1 Field Mobilization / Demobilization

The Site Investigation mobilization will begin with coordination with NAS JAX Public Works for utility clearance and a pre-investigation meeting with NAS JAX personnel. Mobilization will also include all activities associated with preparation for field activities such as coordination with subcontractors (drilling and laboratory) and NAS JAX personnel, preparation of field equipment and materials, and performance of site-specific Health and Safety Plan review meeting for all onsite personnel. The Point of Contact (POC) at NAS JAX is Ms. Jane Mears (904) 772-2717 x139.

3.3.2 Monitoring Well Installation

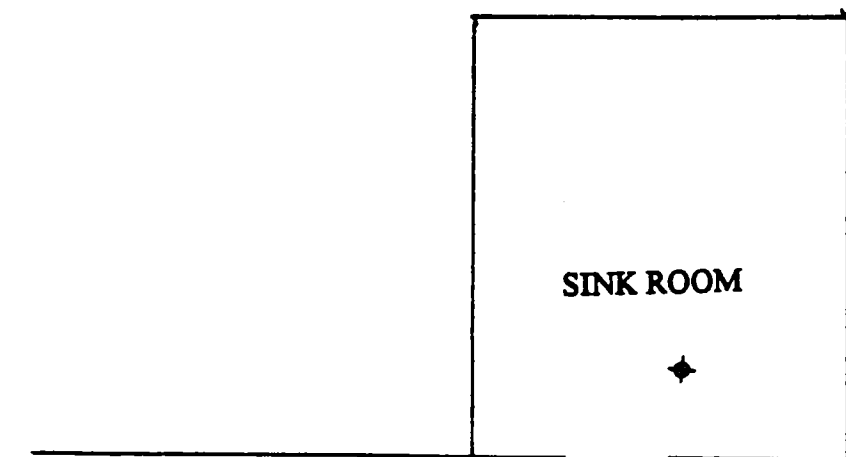
Initially, six groundwater monitoring wells that meet Florida Department of Environmental Protection (FDEP), St. Johns River Water Management District guidelines, and B&R Environmental Standard Operating Procedures (attached in Appendix D) will be installed at the DVECC Building 937 Site. Based on the Navy's estimation of the extent of contamination encountered during the UST removal, it is estimated that the groundwater plume can be defined with five shallow wells (< 15 feet deep) and one deep well (< 30 feet).

Three of the shallow monitoring wells will be installed in a triangular pattern around the former tank location to allow field determination of groundwater flow direction. One shallow well will be installed at the location of the former UST. The final shallow well will be installed inside Building 937 in the former pesticide mixing area. Specialized drilling equipment may be required to complete the well boring inside of Building 937. The deep (vertical extent) well will be installed at the location of the former UST. The estimated depth to groundwater at the site is seven feet bls. Therefore, the shallow monitoring wells will be installed to a depth of approximately 15 feet bls and the deep (vertical extent) well will be installed to a depth of approximately 30 feet bls. Additional monitoring wells may be required based upon the results of the initial round of groundwater samples. All required well permits will be obtained by the drilling subcontractor.



DVECC BUILDING 937

SINK ROOM



FORMER TANK LOCATION

LEGEND

NOT TO SCALE

- ◆ MONITORING WELL
- ⊙ DEEP MONITORING WELL
- SOIL SAMPLE

SITE MANAGER: WSP	CHECKED BY: -
DRAWN BY: TCS	DRAWING DATE:
SURVEYED BY:	SURVEY DATE:
SCALE:	
CAD DWS. NO.:	PROJ. NO.:

**Brown & Root Environmental**

FIGURE 3.1
PROPOSED WELL AND SAMPLE
LOCATIONS
 NAS JAX DVECC
 JACKSONVILLE, FLORIDA

Prior to drilling, each boring location will be evaluated for buried utilities and other obstructions. The Base will have previously located all known utilities in the vicinity of the site. When the location is determined to be free of underground obstructions, the truck mounted drill rig will be positioned over the hole and the boring will be advanced to approximately 15 feet bls (8 feet below the top of the stabilized water table) using hollow-stem augers (HSAs). HSAs with at least an 8.25-inch outside diameter will be used so that 2-inch diameter monitoring wells can be constructed with a minimum of a 2-inch thick annular filter pack and a minimum 2-inch thick annular grout seal completed flush to the land surface.

Wells will be constructed of National Sanitation Foundation (NSF) approved flush-threaded, schedule 40 polyvinyl chloride (PVC). Solvents will not be used when joining sections of pipe. The wells will be constructed with a 10-foot length of 0.02-inch slot PVC screen and sufficient PVC riser to extend the top of the well to ground level. The 10-foot length of screen will allow 8 feet of screen to be in the water table and 2 feet of screen to be above the top of the water table. The vertical extent well will be constructed to a depth of approximately 30 feet. The well used to define the vertical extent will be constructed with a 5-foot length of 0.02-inch slot PVC screen and sufficient PVC riser to extend the top of the well to ground level.

The PVC well string will be used to punch out the temporary bottom plug or check valve in the HSA bit. A silica sand filter pack (10/20 U.S. Standard Sieve size) will be installed around the well screen through the HSAs. The HSAs will be withdrawn from the borehole during filter pack installation to allow the sand to fill the annular space between the well screen and the borehole. A tremie pipe will be used, if necessary, to install the filter pack to at least two foot above the top of the well screen. A 0.5-foot thick interval of fine sand (30/65 sieve size) will be installed as a secondary filter pack on top of the filter pack to serve as a seal. The remaining annular space will be filled with neat cement grout flush to the land surface.

Following the completion of monitoring wells and prior to sampling, the wells will be developed according to local water management regulations using pumping and or swabbing techniques. Monitoring well development will consist of pumping the well until pH, temperature, specific conductance and turbidity have stabilized. Stabilization is considered to have occurred when three consecutive measurements are within 15 percent of one another. A minimum of five borehole volumes will be required.

3.3.3 Groundwater Sampling

Implementation of the sampling procedures has a significant effect on the quality of the analytical data. Therefore, sampling of monitoring wells will consist of the following activities:

- Measurement of depth to water level and total depth of the well (to calculate well volume);
- Decontamination of sampling equipment;
- Evacuation of static water (purging);
- Measurement and recording of groundwater temperature, pH, and specific conductance, and turbidity;
- Collection of the sample;
- Sample preservation and;
- Sample labeling, handling, and transportation via overnight courier to the laboratory.

Decontamination:

All sampling devices and monitoring equipment must be properly decontaminated prior to use. Equipment decontamination must be documented in the logbook. The decontamination process will consist of the following activities:

- Alconox and tap water wash;
- Tap water rinse;
- Reagent Grade Isopropanol rinse (the equipment shall be thoroughly wetted with Isopropanol);
- Analyte-free water rinse;
- Air dry.

Water Level Measurements:

A complete round of water level measurements must be collected prior to any purging or sampling activities. Water level measurements, using an electronic water level indicator, should be taken to the nearest 0.01 foot. Where possible water level measurements shall be taken on the North Side of the monitoring well at the top of the casing, unless a measurement point has been previously established.

Purging Static Water:

- All information concerning the purging of static water including calculations must be recorded for each well. The type of equipment used to purge the well must be described in the logbook. If a pump is utilized information concerning the pump type and flow-rate must be included in the logbook.
- When a bailer is used for purging and/or sampling activities it must be lowered gently into the well such that the formation waters are disturbed as little as possible. It is very important that the turbidity of the sample not be increased by improper purging and/or sampling techniques.

- A minimum of three well volumes of the standing water column will be purged from the well prior to the collection of samples. Monitoring well purging will continue until groundwater temperature, pH, specific conductance, and turbidity has stabilized for three measurements each following the removal of one well volume. If five well are removed then, only one set of water quality measurements is required on final purge volume. No more than five wells volumes shall be removed during purging activities. Over purging the well may result in the collection of non-representative groundwater samples.
- If the well does not recover quickly enough to permit the removal of three well volumes, the well will be pumped or bailed dry and sampled immediately following sufficient recovery. Generally, bailing the well dry once is adequate. Purging will be performed utilizing a properly decontaminated stainless steel or Teflon bailer or the appropriate pump. Utilization of a submersible pump is the preferable method of purging as repeatedly lowering the bailer into the monitoring well may oxygenate the formation waters and change the chemistry of the groundwater.

Lanyards:

- Lanyards may be disposable (braided or monofilament nylon) or reusable (stainless steel Teflon coated).
- A disposable lanyard must be changed for each monitor well. But the same lanyard may used for purging and sampling operations without decontamination between purging sampling activities.
- Reusable lanyards shall be decontaminated between monitoring wells but do not require between purging and sampling operations.
- Lanyards must never come in contact with the ground or other surface which may contaminate the lanyard.

Sample Collection Order:

Samples shall be collected from the least to the most contaminated sampling locations within a site. This information will be obtained from evaluating the October 1995 Tank Closure Report .

Sample Preservation:

Samples must be preserved with the appropriate preservative and maintained on ice. A laboratory certified to perform hazardous waste testing by the Florida Department of Environmental Regulation will

dispatch prepreserved sample containers for collection of samples. It is essential that the samples be maintained at 4 degrees centigrade until delivery to the laboratory facility. A notation must be made on the Chain -of -Custody form (COC) as well as in the logbook concerning sample preservation.

Sample Handling:

It is critical that proper custody procedures be followed throughout all phases of sample collection and handling. Some specific points of concern are as follows: The samples from a particular site must never be commingled with samples from another site. Samples from several sites must never be combined in the same sample cooler. Each sample group must also be under separate documentation (i.e., A COC must be generated for each site and for each sampling event). The Site Manager as well as the individual who releases the samples to the transporter must follow up to see if the samples were received at the laboratory facility.

Sample Identification:

Sample nomenclature must be unique and must always include the date of sample collection. Each sample is assigned a series of codes indicating the site, sample type, sample location, sample depth and sample round. The sample nomenclature system has been designed to maintain consistency between field, laboratory, and data base sample numbers. In addition, the system facilitates cost-effective data evaluation as data can be easily sorted by matrix and/or by depth, etc.

All samples must be identified utilizing the following format :

Media:	Site	Sample Type	Location	Depth	Round
Groundwater	937	GW	Well No.	01	01
Soil	937	SO	Boring No.	01, 02, etc.	01

For example, a groundwater sample collected for this project for monitoring well JAX-937-003 would have the following sample ID: **937-GW-003-01-01**. Its duplicate sample would be designated: **937-GW-003-02-01**

A soil sample collected for this project from soil boring SB-05 from 0.0'-2.0' would have the following sample ID: **937-SO-005-01-01**. The next soil sample from that boring (independent of depth) would have the following sample ID: **937-SO-005-02-01**. Duplicates will be designated by incrementing the Depth field

one value as if it were a separate depth. Depth intervals (and duplicates) for each soil sample will be documented on the soil boring log and soil sample log form.

The Sample Type field will also designate Quality Control Samples as follows:

TB - Trip Blank
FB - Field Blank
RB - Rinsate Blank

Field Quality Control samples will be numbered sequentially (e.g., TB-001, TB-002, etc.)

Sampling procedures will be according to the B&R Environmental Comprehensive Quality Assurance Plan (FDEP COMPQAP #870055G, 1996) and USEPA Region IV Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM, 1996). The groundwater samples will be analyzed using accelerated laboratory TAT for the compounds of concern in Table T-1 (Appendix A). Analytical methods will use the Method Detection Limits presented in Table 5.2 (Appendix A).

3.3.4 Soil Boring Drilling and Soil Sampling

During the drilling of each monitoring well boring, soil samples will be collected continuously from the ground surface to the termination depth of the boring for visual lithological classification. Soil samples will be screened for volatile organics volatiles, according to the site-specific Health and Safety Plan, in the field using a flame ionizing organic vapor analyzer (OVA). Two soil samples from each well boring will be collected for laboratory analysis; one foot below land surface (BLS), and one foot above the water table. These soil samples will be submitted to the analytical laboratory for accelerated analysis.

The location of the eight additional soil borings will be determined based upon the location of the former UST, analytical results of soil samples collected during the Bechtel, Inc. tank closure activities in October of 1995, and the results of the soil samples collected from the six initial well borings. This will allow for optimal placement of the soil borings to define the nature and extent of soil contamination. Two soil samples from each well boring will be collected for laboratory analysis; one foot below land surface (BLS), and one foot above the water table. These soil samples will be submitted to the analytical laboratory for accelerated analysis. Anticipated sampling locations are presented on Figure 3-1.

Soil sampling will be performed in accordance with B&R Environmental SOPs (Appendix C) using a drill rig equipped with hollow-stem augers and a 2-inch diameter, 18 or 24 inch long, split-spoon sampler, as

appropriate. Split-spoon samplers are advanced with appropriate conventional methods. The sampler is driven with a standard 140-pound hammer following ASTM Specification D-1586. Blow counts are recorded in 6-inch intervals for the total sample depth. Borings will be advanced to the top of the water table. Upon completion of the borehole, the open hole will be back-filled with a cement-bentonite grout mixture.

Prior to the initiation of drilling activities or advancing to the next drilling location, the drill rig and equipment will be decontaminated in accordance with the approved FDEP COMPQAP.

Sampling and decontamination procedures will be according to the B&R Environmental Comprehensive Quality Assurance Plan (FDEP COMPQAP #870055G, 1996) and USEPA Region IV Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM, 1996). The soil samples will be analyzed using accelerated laboratory TAT for the compounds of concern in Table T-1 (Appendix A). Analytical methods will use the Method Detection Limits presented in Table 5.2 (Appendix A).

3.3.5 Quality Control Samples

Quality control is the overall system of activities whose purpose is to document and control the quality of the environmental data so that it meets the DQOs. The QC measures that will be employed during the investigations at the subject site will consists of the following: Equipment Blanks (Precleaned and Field cleaned) and Duplicate samples. The definition and method of collection for each of these is defined below:

- **Trip Blanks** - These blanks are required for Volatile Organic Carbon (VOC) samples, only. VOC sampling is not being performed as part of this task therefore no trip blanks are required.
- **Equipment Blanks** - Blanks that are prepared on-site by pouring analyte-free water over decontaminated equipment and collecting into sample container(s). Appropriate sample containers, for each analyte group must be used, preservatives added, if required, and appropriate documentation completed. These blanks are stored, transported and analyzed along with the intended sample groups and will be analyzed for the same parameters required by the sample group. At least one equipment blank is required for each water and solid matrix analytical sample group, and must be collected **at the beginning** of the sampling episode. If decontamination is performed in the field then a field cleaned equipment blank must be collected for all water and solid matrix sample groups. When collecting precleaned and field cleaned equipment blanks it is essential that the equipment used is

identified with the proper blank. And sampling groups identified with the equipment decontamination procedure (i.e., field cleaned or precleaned).

- **Duplicates** - Field duplicates shall be collected and analyzed for the same parameters as the associated samples. They shall be preserved, transported and documented in the same manner as the original samples. These samples are not considered laboratory duplicates but serve to measure of the variability inherent in the sampling process. They must be obtained by DUPLICATING the entire sample acquisition technique that was used to obtain the original sample.
 - a. Duplicate samples for water are collected by sampling from successively collected volumes (i.e., samples from the next bailer of sample water).
 - b. Duplicates samples for soils are collected from the sample source (i.e., soil is obtained from the same soil sampling device).

3.3.6 Equipment Decontamination

Sampling equipment and methods have been chosen to minimize the possibility of cross-contamination. Any sampling item which can not be effectively decontaminated such as tubing, hoses, lanyards, etc. will be disposed of after sampling. The decontamination procedures for investigation/sampling equipment will be as follows:

- Steam clean (drilling equipment only);
- Scrub with tap water and laboratory grade detergent (e.g., Alconox or Liquinox) solution using a brush if necessary to remove surface films and particulate matter;
- Rinse with tap water;
- Rinse with nanograde or equivalent Isopropanol, making sure to thoroughly wet all surfaces;
- Rinse with analyte-free water and allow to air dry;
- If equipment is to be stored or transported, wrap with aluminum foil to prevent contamination.

Teflon sampling implements used for collecting samples for organic and/or metals analysis will require the following decontamination procedure:

- Scrub with tap water and laboratory grade detergent (e.g., Alconox or Liquinox) solution using a brush if necessary to remove surface films and particulate matter;
- Rinse with tap water;
- Rinse with 10% nitric acid solution;
- Rinse with tap water;

- Rinse with nanograde or equivalent Isopropanol, making sure to thoroughly wet all surfaces;
- Rinse with analyte-free water and allow to air dry;
- If equipment is to be stored or transported, wrap with aluminum foil to prevent contamination.

3.3.7 Investigation-derived Waste Management

Development water, decontamination water, and purge water will be containerized in D.O.T. approved, 55-gallon drums and characterized based on analytical results of the groundwater monitoring wells. All soil cuttings will also be containerized in 55-gallon drums. One composite soil sample will be collected from the soil drums for TCLP characterization of pesticides and herbicides. Investigation-derived wastes (IDW) will be disposed of by NAS JAX Public Works Center.

3.3.8 Slug Tests

B&R Environmental will perform a series of duplicate slug tests on two selected shallow monitoring wells and the deep well at the site. These tests involve lowering a solid slug into each well, allowing the water level to equilibrate, and suddenly removing the slug to cause an "instantaneous" drop in the water level in the well. The rate at which the water level recovers is related to the hydraulic conductivity of the aquifer material immediately surrounding that monitoring well.

The rise in water level versus time will be measured and recorded using a standard pressure transducer probe connected to an electronic data logger. The slug test data will be reduced using the Bouwer and Rice (1976) methodology for partial penetrating wells in unconfined aquifers in order to calculate the hydraulic conductivity values for each of the three monitoring wells. Each test will be duplicated and the values averaged. The results of the tests will be used to assist in the determination of potential groundwater contaminant plume migration.

3.3.9 Custody Procedures

The use of Chain-of-Custody (COC) protocols will ensure data usability and establish the evidentiary integrity of samples and/or sample containers. It can be used to demonstrate that the sample containers and samples were handled and transferred in such a manner to eliminate possible tampering. As such, these protocols are advantageous if data is to be used in legal cases such as law suites, criminal actions, and enforcement actions.

COC begins at the laboratory with the release of the empty sample containers and must be maintained and documented from that point forward, up to and including sample destruction. The COC can be maintained by observing the following protocols:

- Sample containers must be released under signature from the laboratory and must be accepted under signature by the sampler(s) or responsible individual who will maintain custody until such time the sample containers are transferred to the sampler(s).
- Sample containers and samples in someone's physical possession, locked in a secured storage area or by sealing the storage container with and maintaining an intact custody seal.
- Transport containers must be sealed with strapping tape and a tamper proof custody seal. The custody seal must contain the signature of the individual releasing the transport container, along with the date and time.
- COC forms must remain with the samples during transport or shipment. They must be placed in a waterproof closure inside the sealed transport container.
- The COC form must account for all time periods associated with the samples and must include signatures of all individuals actively involved with physically handling the samples.

The COC record must specifically contain the following information:

1. Sampling site name and address
2. Date and time of sample collection
3. Unique field ID code for each sample source and container
4. Name of personnel collecting samples
5. Time of day and calendar date of all custody transfers
6. Signatures of all transferors and transferees
7. Clear indication of number of sample containers
8. Required analyses (by approved method number)
9. Sample preservation information
10. Common carrier usage, if applicable

3.3.10 Field Documentation

The following information must be documented and maintained in the project records. This information may be record into bound field logbooks or on field sheets which have been designed for a specific purpose. All unbound or loose records (i.e., field sheets, photographs, etc.) must be unequivocally linked to the sampling event by code, facility name and/or client name and address.

a. General Information - the following information must be recorded during all sampling events:

1. Names of all personnel and visitors on site during field activities.
2. Date and time (military time preferred) of the individual task completed while on site.
3. Ambient field conditions, to include, weather, tides, etc.
4. Specific description of the event location including site name and address. The specific sampling location, well installation location or soil boring location.
5. Field ID No. for each sample container and parameters to be analyzed.
6. Field measurement data (e.g., pH, specific conductance, temperature, etc.).
 - a. Records must indicate when measurements were taken; and
 - b. Calibration information to include: time of all calibrations or calibration checks, concentration(s) of calibrates and calibration acceptance.
7. Sample sequence - identify the order in which each sample is taken (time of sample collection is acceptable).
8. Preservative used; all sample containers will be prepreserved by the laboratory analyzing the samples.
9. Field decontamination performed. All field-sampling equipment decontamination, whether performed in the field or at a laboratory, or at the headquarters facility must be documented.
10. Purging and sampling equipment used (ID No. if applicable).
11. Types of QC samples collected. Include when and where collected and type (e.g., trip blank, equipment blank, duplicate, etc.).
12. Composite samples, if collected, must indicate number of samples included in the composite and approximate amount/quantity of each subsample or aliquot.
13. Signature of sampler(s).

b. Additional documentation for monitoring wells shall include:

1. Well casing composition and diameter of well casing
2. Water table and well depth
3. Calculations used to determine purge volume

4. Purging rate (i.e., the rate at which water is withdrawn from the well (gpm))
5. Total amount of water purged
6. Date well was purged
7. Beginning and ending purge times (military time preferred)
8. Measurement data (i.e., pH, conductivity, temperature, color, turbidity, etc.) used to monitor stabilization, if applicable

c. Additional documentation for sediments and soils must include:

1. Depth from the surface that samples were taken
2. Drilling/boring method

3.3.11 Equipment Calibration

All instruments and equipment used during sampling and analysis will be maintained, calibrated and operated in accordance with manufacturer's specifications as well as recommendations and criteria prescribed in specific method references. Maintenance, calibration and operation will be performed by personnel properly trained in these procedures. Documentation of special or routine maintenance and calibration will be maintained in logbooks dedicated to each piece of equipment. In the event that equipment is rented, B&R Environmental will obtain proof of proper maintenance and calibration, which will be maintained with project records. Brief descriptions of calibration procedures for major field instruments follow.

Organic Vapor Analyzer

Procedures for regular maintenance, calibration and pump system check for the Foxboro OVA-128 instrument are as follows:

- **Maintenance**
 - Check filters daily.
 - Check pumping system daily.
 - Check calibration daily.
 - Check quad rings weekly.
 - Clean burner chamber weekly.
 - Factory maintenance yearly.

- **Calibration**

- Remove instrument from the case.
- Turn on the instrument and zero on the X10 scale. Gas select dial at 300 for methane calibration.
- Turn on pump and hydrogen. Ignite instrument. Place in survey mode.
- Introduce a methane standard near 100 ppm. The standard shall be placed in a Tedlar bag and withdrawn by the instrument. Gas standard must not be forced into the instrument.
- Adjust R-32 trimpot on circuit board to make the instrument read to standard.
- Extinguish the flame and adjust meter needle to read 4 ppm.
- Switch to X1 scale and adjust R-31 trimpot to make meter read 4 ppm.
- Return to X10 scale and adjust meter needle to 40 ppm.
- Switch to X100 scale and adjust R-33 trimpot to make the meter read 40 ppm.

Conductivity Meter

Specific conductance is a useful method to approximate the total amount of inorganic dissolved solids. Conventional conductivity devices consist of two or more platinum electrodes separated by a test solution. Conductivity systems based on the measurement of inductance or capacitance are also available.

The meter will be checked in one of three ways:

1. Follow method specifications.
2. Use two standard potassium chloride solutions of 100 and 1,000 umhos/cm or standards that bracket the range of expected sample conductance.
3. A single check standard in each range of a multi-range instrument.

pH Meter

The pH meter is field calibrated on a daily basis. Field meters that have been transported from site to site will require a calibration check, as calibration is likely to change during transport.

There are several items to keep in mind with pH measurement:

1. Coatings of oil, greases, and particulates may impair the electrode's response. The electrode bulb should be patted dry with lint-free paper or cloth and rinsed with deionized water. If, not acetone can

be used to clean very hard to remove films, but must be used sparingly to avoid damaging the electrode's surface.

2. Temperature effects on the electrometric measurement of pH are controlled by using instruments having temperature compensation or by calibrating the meter at the temperature of the samples.
3. Poorly buffered solutions with low specific conductance (<200 umhos/cm) may cause fluctuations in the pH readings. Equilibrate electrode by immersing in several aliquots of sample before taking pH reading.
4. Check the battery before mobilizing to the field and turn on the meter when you reach the facility and allow it to equilibrate to ambient temperature.
5. After the initial calibration, the pH meter shall be checked against the pH 7 buffer at intervals of no more than 4 hours.
6. The meter will be checked against the pH 7 buffer after sampling has been completed.
7. If the sampling event takes less than 4 hours, then an initial and post-calibration check will be adequate.
8. If during continuing calibration, the response is greater than .2 pH units on either side of 7, then a complete initial calibration must be conducted.
9. All initial and continuing calibrations must be completely documented in bound logbooks or field sheets, including: date/time, standard(s) used, resultant meter response, action taken, and technician initials.

3.4 **PROPOSED LABORATORY ANALYSIS**

This investigation falls under the RCRA guidelines SW-846 analytical method for the identification of environmental contaminants are appropriate. The soil and groundwater samples will be analyzed using EPA methods 8081, 8151, and 8141. These analyses will use the MDLs listed in Table 5.2 (Appendix A) to detect the compounds of concern listed in Table T-1 (Appendix A). Additional engineering parameters will be collected to support potential remedial alternatives. One groundwater sample will include total organic carbon (TOC), total and dissolved iron and manganese, and total suspended solids (TSS). One soil sample will include total organic carbon (TOC) and natural moisture content. Table 3-1 presents a sampling analysis summary. Recommended sample containers, sample volumes, preservation techniques and holding times for soil and groundwater samples are presented in Tables 3-2 and 3-3 respectively.

**TABLE 3-1
SAMPLING ANALYSES SUMMARY
NAS-JAX DVECC, FLORIDA**

Sample Type	Analytical Method ⁽¹⁾	Approx. No. Environmental Samples	No. Replicate Samples ⁽²⁾	No. Trip Blanks ⁽²⁾	No. Equipment Blanks ⁽²⁾	Total No. Samples
Groundwater	EPA Methods 8081, 8151, and 8141	6	1	1		8
	TOC (SW 9060)	1	0	0	0	1
	TSS (E 160.2)	1	0	0	0	1
	Fe, Mn (SW 6010)	2 (tot./dis.)	0	0	0	2
Subsurface Soil from well installation	EPA Methods 8081, 8151, and 8141	12	1		1	14
	TOC (Modified SW9060)	1	0	0	0	1
	Moisture (ASTM D 2216)	1	0	0	0	1
Subsurface Soil from soil borings	EPA Methods 8081, 8151, and 8141	16	1		1	18

- ⁽¹⁾ EPA Method 8081 - Organochlorine Pesticides and PCBs.
EPA Method 8151 - Chlorinated Herbicides.
EPA Method 8141 - Organophosphorus Compounds

- ⁽²⁾ Terms used in table as per Appendix A of the FDEP COMPQAP #870055G.

TABLE 3-2
RECOMMENDED SAMPLE CONTAINERS, SAMPLE VOLUMES, PRESERVATION TECHNIQUES
AND HOLDING TIMES FOR RESIDUALS, SOIL AND SEDIMENT SAMPLES (1)

<u>PARAMETER GROUP</u>	<u>METHODS</u>	<u>CONTAINER</u>	<u>PRESERVATION</u>	<u>MAX HOLDING TIMES</u>
Organochlorine Pesticides	8081, 8151	Glass, 8 oz. wide mouth	(3)	14 days until
PCBs.	8141	with Teflon lined cap		extraction, 40 days
Chlorinated Herbicides.		(50 gram sample)		after extraction
Organophosphorus Compounds				

-
- (1) Adopted from tables 3-1 and 4-1 in Test Methods for Evaluating Solid Waste, SW-846, EPA, Third Edition, 1986, and First Updated in 1987. The term residuals includes: (i) concentrated waste samples and (ii) sludges of domestic or industrial origin.
- (2) Sample shall not be homogenized (mixed) prior to filling container. Container must be filled by packing as much sample into it leaving minimal head space. Field samples can not be composited for analysis.
- (3) Soils, sediments and sludges shall be kept cool at 4 degrees centigrade from collection time until analysis. No preservation is required for concentrated waste samples.

Reference: Chapter 62-160.700, F.A.C., Table 5

TABLE 3-3
RECOMMENDED SAMPLE CONTAINERS, SAMPLE VOLUMES, PRESERVATION TECHNIQUES
AND HOLDING TIMES FOR GROUNDWATER SAMPLES

<u>PARAMETER GROUP</u>	<u>METHODS</u>	<u>CONTAINER</u>	<u>PRESERVATION</u>	<u>MAX HOLDING TIMES</u>
Organochlorine Pesticides	8081, 8151,	1/2 gallon amber glass	Cool, 4 c	7 days until
PCBs	8141	bottles with Teflon		extraction, 40 days
Chlorinated Herbicides		lined caps		after extraction.
Organophosphorus				
Compounds				

{a} Volatile samples for aromatic and haloethane compounds should be preserved with sodium bisulfate or HCL to a pH<2.

{b} Any water samples suspected to contain residual chlorine (e.g., chlorine-treated water) will be preserved with a 10 % solution of sodium thiosulfate before analysis for pesticides/PCBs.

Source: 40 CFR, Part 136, July 1, 1987

3.5 CONTINGENCY PLAN

In the event of problems which may be encountered during site activities, the Field Operations Leader (FOL) will immediately notify the B&R Environmental Task Order Manager (TOM) and NAS JAX POC. The TOM will immediately notify the SOUTHNAVFAC POC. The TOM, SOUTHNAVFAC POC, and DVECC POC will determine a course of action that will prevent or minimize impact to the facility operations, schedule, data quality, or budget. All contingency plans will be approved through the SOUTHNAVFAC POC before being enacted. A Filed Task Modification Form will be completed by the FOL documenting the selected contingency plan.

4.0 REPORT

Upon completion of all field work and laboratory analysis, B&R Environmental will prepare a Site Investigation Report summarizing the results of the investigation. The report will include the following items:

- Site history and current land use;
- Investigation description - boring / groundwater monitoring well placement and rationale;
- Sensitive receptors and migration pathways;
- Site hydrologic conditions, including slug test data and calculations;
- Site and regional geology;
- Summary of findings;
- Options for obtaining clean closure of the site;
- Figures and maps - site location, site groundwater flow direction, contaminant isoconcentration plumes, and potable wells within 1/2 mile;
- Tables - groundwater elevation and soil and groundwater analytical data summaries;
- Boring logs and groundwater monitoring well diagrams;
- Laboratory analytical data and chain-of-custody forms;
- References.

Following the Navy's review and approval of the report, the Navy will submit the Site Investigation Report to the FDEP.

5.0 PROPOSED SCHEDULE

Well installation and sampling (six wells) and initial soil sampling is proposed to begin in early January 1997 and take approximately one week to 10 days to complete. Chemical analysis will be performed using an accelerated laboratory TAT. Based upon the resulting of the initial sampling, approximately eight additional soil boring will be drilled and sampled. This is scheduled to begin one week following receipt of laboratory data and will take approximately 5 days to complete. The draft Site Investigation Report will be completed by mid-February 1997. Following the receipt of any Navy comments to the draft report, the final Site Investigation Report will be completed within 10 days.

6.0 REFERENCES

Bouwer, H. and R. C. Rice, 1976. "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells" Water Resources Research, V. 12, pp. 423-428.

Brown & Root Environmental, Comprehensive Quality Assurance Plan, FDEP COMPQAP #870055G, 1996.

Brown & Root Environmental, Standard Operating Procedures, 1994.

Rust Environment and Infrastructure Inc. 1996. "Closure Activities Reported and Certifications for DVECC Tank and Drains at Building 937", Rust Environment and Infrastructure Inc., 2694 Lake Park Drive, North Charleston, South Carolina, 29406

SOUTHNAVFAC, NAS JAX letter to Florida Department of Environmental Protection, October 24, 1995.

USEPA, Guidance for the Data Quality Objectives Process, USEPA QA/G-4, 1994.

USEPA, Region IV, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM, 1996).

APPENDIX A

October 24, 1995 NAS JAX Letter to FDEP

TABLE 5.2. LABORATORY ANALYTICAL METHODS, QA OBJECTIVES AND METHOD DETECTION LIMITS (MDL) FOR SOLIDS AND SEMISOLIDS

PARAMETER	METHOD (Prep)	REFERENCE	ACCURACY* (X Rec)	PRECISION* (X RPD)	MDL** (ug/kg)	Reporting Limit (ug/kg)
2,4-D (MS)	8150	2	10-130	0-47	1.3	8.3
Dalapon	8150	2	10-170	0-60	16	2000
2,4-DB	8150	2	20-160	0-40	0.74	8.3
Dicamba	8150	2	20-160	0-40	0.54	20
Dichlorprop	8150	2	30-170	0-40	1.8	100
Dinoseb	8150	2	30-170	0-40	0.92	100
MCFA	8150	2	30-170	0-40	350	2000
MCPP	8150	2	30-170	0-40	290	2000
Pentachlorophenol	8151	2	10-150	0-40	4.3	17
Picloram	8150***v	2	10-150	0-40	1.6	3.3
2,4,5-T (MS)	8150	2	24-115	0-46	0.22	8.3
2,4,5-TP (Silvex) (MS)	8150	2	10-150	0-54	0.18	8.3
Surrogate - 2,4-Dichlorophenoxy butanoic acid (2,4-DB)	8150	2	20-160	NA	NA	NA
Surrogate - 2,4-Dichlorophenyl acetic acid (DCAA)	8150	2	10-160	NA	NA	NA

TABLE 5.2. LABORATORY ANALYTICAL METHODS, QA OBJECTIVES AND
 METHOD DETECTION LIMITS (MDL) FOR SOLIDS AND SEMISOLIDS

PARAMETER	METHOD (Prep)	REFERENCE	ACCURACY* (% Rec)	PRECISION* (% RPD)	MDL** (ug/kg)	Reporting Limit (ug/kg)
Monocrotophos	8141(3550)	2	40-140	0-50	22	330
Malathion	8141(3550)	2	54-102	0-40	6.9	330
Carbaryl	8141(3550)	2	40-140	0-50	8.2	33
Permethrin, ethyl (MS)	8141(3550)	2	15-141	0-79	3.2	33
Permethrin, methyl (MS)	8141(3550)	2	40-140	0-40	6.2	17
Permethrin	8141(3550)	2	22-172	0-50	8.2	33
Phorate	8141(3550)	2	36-125	0-40	8.2	33
Prothion	619/8141(3550)	2	40-140	0-50	16	66
Prothion	619/8141(3550)	2	40-140	0-50	16	66
Prothion	619/8141(3550)	2	40-140	0-50	16	66
Ronnel (MS)	8141(3550)	2	22-127	0-35	23	33
Sulfazine	619/8141(3550)	2	20-150	0-50	16	66
Selphos (Tetrachlorvinphos)	8141(3550)	2	48-125	0-40	8.2	33
Sulfotop (MS)	8141(3550)	2	13-171	0-65	4.2	17
Terbufos	8141(3550)	2	40-140	0-50	6.2	17
Terbutryn	619/8141(3550)	2	40-140	0-50	22	330
Terbutylazine	619/8141(3550)	2	40-140	0-50	16	66
Thionazin (MS)	8141(3550)	2	25-160	0-60	16	33
Takuthion (Prochloros)	8141(3550)	2	44-125	0-40	3.2	33
Triedimeton	8141(3550)	2	40-140	0-50	8.2	33
Trichloronate	8141(3550)	2	49-161	0-40	22	330
Triphos	8141(3550)	2	40-140	0-50	55	360
Vernolate	8141(3550)	2	39-147	0-45	16	66
Surrogate - Triphenylphosphate	8141(3550)	2	40-125	NA	NA	NA

TABLE 5.2. LABORATORY ANALYTICAL METHODS, QA OBJECTIVES AND METHOD DETECTION LIMITS (MDL) FOR SOLIDS AND SEMISOLIDS

PARAMETER	METHOD (Prep)	REFERENCE	ACCURACY* (% Bias)	PRECISION* (% RPD)	MDL** (ug/kg)	Reporting Limit (ug/kg)
Heptachlor epoxide	8080(3550) CLP 3/90	2 62	37-142 NA	0-40 NA	0.47 1.7	1.7 1.7
Iodrin	8081(3550)	2	10-150	0-50	0.65	3.3
Kepone	8081(3550)	2	10-150	0-50	4.2	17
Methoxychlor	8080(3550) CLP 3/90	2 62	34-166 NA	0-40 NA	3.6 17	17 17
Mirex	8081(3550)	2	20-100	0-50	8.2	33
Pendimethalin	8080***v(3550)	2	35-125	0-50	17	67
Permethrin (total)	8080***v(3550)	2	40-160	0-50	8.2	33
Proachlor	8081(3550)	2	51-125	0-30	4.0	16
Toxaphene	8080(3550) CLP 3/90	2 62	41-126 NA	0-50 NA	34 170	170 170
Trifluralin	8081(3550)	2	40-160	0-40	0.33	0.33
Triethion	8080***v(3550)/ 8081(3550)	2	76-120	0-19	3.3	3.3
PCB-1016	8080(3550) CLP 3/90 EPA-600/4-81-045	2 62 61	52-152 NA 50-130	0-31 NA 0-50	4.6 33 1200	33 33 5000
PCB-1221	8080(3550) CLP 3/90 EPA-600/4-81-045	2 62 61	15-178 NA 50-130	0-20 NA 0-50	8.8 67 1200	67 67 5000
PCB-1232	8080(3550) CLP 3/90 EPA-600/4-81-045	2 62 61	10-215 NA 50-130	0-20 NA 0-50	13 33 1200	33 33 5000
PCB-1242	8080(3550) CLP 3/90 EPA-600/4-81-045	2 62 61	39-150 NA 50-130	0-20 NA 0-50	15 33 1200	33 33 5000
PCB-1248	8080(3550) CLP 3/90 EPA-600/4-81-045	2 62 61	38-158 NA 50-130	0-20 NA 0-50	5.0 33 1200	33 33 5000
PCB-1254	8080(3550) CLP 3/90 EPA-600/4-81-045	2 62 61	66-122 NA 50-130	0-25 NA 0-50	5.2 33 1200	33 33 5000
PCB-1260	8080(3550) CLP 3/90 EPA-600/4-81-045	2 62 61	58-122 NA 50-130	0-20 NA 0-50	13 33 1200	33 33 5000
Surrogate - Dibutylchlorodate (DBC)	8080(3550)	2	45-131	NA	NA	NA
Surrogate - 2,4,5,6-Tetrachloro- xylene (TOX)	8080(3550) CLP 3/90	2 62	19-132 60-150	NA NA	NA NA	NA NA
Surrogate - Decachlorobiphenyl (DCB)	8080(3550) CLP 3/90	2 62	47-126 60-150	NA NA	NA NA	NA NA

Section 5

Revision: 1

Date: 9/94

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TABLE 5.2. LABORATORY ANALYTICAL METHODS, QA OBJECTIVES AND METHOD DETECTION LIMITS (MDL) FOR SOLIDS AND SEMISOLIDS

PARAMETER	METHOD (Prep)	REFERENCE	ACCURACY* (% Rec)	PRECISION* (% RPD)	MDL** (ug/kg)	Reporting Limit (ug/kg)
Aldrin (MS)	8080(3550) CLP 3/90	2 62	40-137 34-132	0-39 0-43	0.58 1.7	1.7 1.7
Benfluralin	8080***v(3550)	2	40-140	0-40	0.33	0.33
alpha-BHC	8080(3550) CLP 3/90	2 62	37-134 NA	0-40 NA	0.19 1.7	1.7 1.7
beta-BHC	8080(3550) CLP 3/90	2 62	17-147 NA	0-40 NA	0.24 1.7	1.7 1.7
gamma-BHC (Lindane) (MS)	8080(3550) CLP 3/90	2 62	41-134 44-127	0-36 0-50	0.26 1.7	1.7 1.7
delta-BHC	8080(3550) CLP 3/90	2 62	19-140 NA	0-40 NA	0.40 1.7	1.7 1.7
technical Chlordane	8080(3550)	2	45-119	0-40	3.5	17
alpha Chlordane	8081(3550) CLP 3/90	2 62	45-140 NA	0-40 NA	0.44 1.7	1.7 1.7
gamma Chlordane	8081(3550) CLP 3/90	2 62	45-140 NA	0-40 NA	0.42 1.7	1.7 1.7
Chlorobenzilate	8081(3550)	2	50-150	0-40	5.2	17
Chloroneb	8081(3550)	2	49-125	0-30	3.2	13
Chloropropylate	8081(3550)	2	51-125	0-30	4.0	16
Chlorothalonil	8081(3550)	2	35-130	0-40	1.7	6.7
Dacthal	8080***v(3550)/ 8081(3550)	2	75-127	0-27	0.057	0.33
4,4'-DDB	8080(3550) CLP 3/90	2 62	31-141 NA	0-50 NA	1.1 3.3	3.3 3.3
4,4'-DDE	8080(3550) CLP 3/90	2 62	30-143 NA	0-50 NA	0.27 3.3	3.3 3.3
4,4'-DDT (MS)	8080(3550) CLP 3/90	2 62	48-150 23-134	0-34 0-50	0.60 3.3	3.3 3.3
Dicofol (Kelthane)	8081(3550)	2	40-125	0-40	1.7	20
Dieldrin (MS)	8080(3550) CLP 3/90	2 62	42-139 31-134	0-41 0-38	0.35 3.3	3.3 3.3
Endosulfan I	8080(3550) CLP 3/90	2 62	45-153 NA	0-40 NA	0.43 1.7	1.7 1.7
Endosulfan II	8080(3550) CLP 3/90	2 62	10-202 NA	0-65 NA	2.8 3.3	3.3 3.3
Endosulfan sulfate	8080(3550) CLP 3/90	2 62	26-144 NA	0-50 NA	0.76 3.3	3.3 3.3
Endrin (MS)	8080(3550) CLP 3/90	2 62	44-151 42-139	0-31 0-45	0.30 3.3	3.3 3.3
Endrin aldehyde	8080(3550) CLP 3/90	2 62	10-150 NA	0-50 NA	1.1 10	3.3 10
Endrin ketone	8080***v(3550)/ 8081(3550) CLP 3/90	2 62	40-100 NA	0-31 NA	0.033 3.3	3.3 3.3
Etridifazole	8081(3550)	2	50-125	0-30	0.33	0.33
Heptachlor (MS)	8080(3550) CLP 3/90	2 62	40-136 33-130	0-34 0-31	0.20 1.7	1.7 1.7

TABLE T-1
 CLEAN CLOSURE TARGET LEVELS
 DVECC TANK SYSTEM CLOSURE
 BUILDING 937 - NAS JACKSONVILLE

PARAMETERS OF CONCERN	CLEAN CLOSURE TARGET LEVELS	
	AQUEOUS (ug/l)	SOLID (ug/kg)
aldrin	0.05	1.70
alpha-BHC	0.05	1.70
beta-BHC	0.10	1.70
chlordane	2.0	1.70
2,4-D	70.0	8.30
4,4-DDD	0.10	3.30
4,4-DDE	0.10	3.30
4,4-DDT	0.10	3.30
dieldrin	0.10	3.30
endosulfan (I and II)	0.35	1.70/3.30
endosulfan sulfate	0.30	3.30
endrin	2.0	3.30
endrin aldehyde	0.10	3.30
heptachlor	0.40	1.70
heptachlor epoxide	0.2	1.70
lindane (G-BHC)	0.2	1.70
methoxychlor	40.0	17.0
silvex (2,4,5-TP)	50.0	8.30
toxaphene	3.0	170.0
delta - BHC	0.50	1.70
dinoseb	7.0	100.0
isodrin (aldrin isomer)	0.0099	3.30
parathion (ethyl/methyl)	42.0	33.0/17.0

NAVFAC
DVECC

5090
Code 184JM/12

24 OCT 1995

Mr. Stanley Tam
Hazardous Waste Engineer
Florida Department of Environmental Protection
Northeast District
7825 Baymeadows Way, Suite 2008
Jacksonville, FL 32256-7590

RE: NAVAL AIR STATION JACKSONVILLE FL6 170 024 412
HF16-230808 - DVECC TANK
DUVAL COUNTY - HAZARDOUS WASTE

Dear Mr. Patel:

This letter is to advise you that the solids "Target Levels" in the referenced permit should have listed the "Reporting Limits" as provided in Table 5.2 of our February 15, 1995 letter. Enclosed are copies of Tables 5.2 along with our revised Table T-1. The Method Detection Limits (MDL) are utilized to confirm that a particular laboratory can meet the quality requirements for the detection limits established for pure samples of each compound. The MDL cannot be used for determining if a field sample is contaminated. We are proposing to use the "Reporting Limits" as the "Below Detection Limit" (BDL) per DEP's request in the December 1, 1994 item #8.

If you have questions, please contact Ms. Jane Mears, Facilities and Environmental Department, at (904) 772-2717, extension 139.

Sincerely,

KEVIN H. GARTLAND
GM-13, Environmental Division Director
By direction of the Commanding Officer

Enclosure

Copy to:

COMNAVBASE JAX (N3)

→ Rust Environment & Infrastructure

APPENDIX B

Field Forms



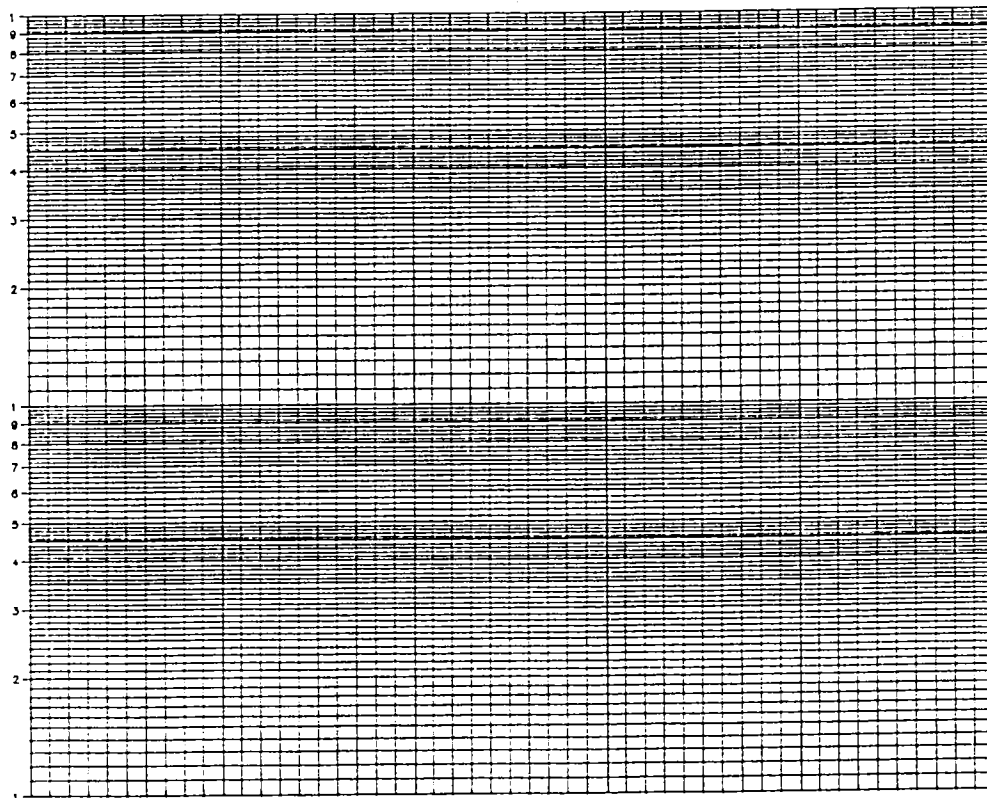
MONITORING WELL SHEET

PROJECT _____ LOCATION _____
 PROJECT NO. _____ BORING _____
 ELEVATION _____ DATE _____
 FIELD GEOLOGIST _____

DRILLER _____
 DRILLING _____
 METHOD _____
 DEVELOPMENT _____
 METHOD _____

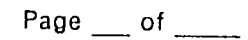
	Ground Elevation _____	ELEVATION TOP OF RISER: _____
		TYPE OF SURFACE SEAL: _____
	Flush mount surface casing with lock	TYPE OF PROTECTIVE CASING: _____
		I.D. OF PROTECTIVE CASING: _____
		DIAMETER OF HOLE: _____
		TYPE OF RISER PIPE: _____
		RISER PIPE I.D.: _____
		TYPE OF BACKFILL/SEAL: _____

		DEPTH/ELEVATION TOP OF SAND: _____ / _____
	DEPTH/ELEVATION TOP OF SCREEN: _____ / _____	
	TYPE OF SCREEN: _____	
	SLOT SIZE x LENGTH: _____	
	TYPE OF SAND PACK: _____	
	DIAMETER OF HOLE IN BEDROCK: _____	
	DEPTH/ELEVATION BOTTOM OF SCREEN: _____ / _____	
	DEPTH/ELEVATION BOTTOM OF SAND: _____ / _____	
	DEPTH/ELEVATION BOTTOM OF HOLE: _____ / _____	
	BACKFILL MATERIAL BELOW SAND: _____	

[illegible]

REMARKS:

CALCS, SKETCH MAPS, ETC.:



Well: _____ Depth to Bottom (ft.): _____ Responsible Personnel: _____
 Site: _____ Static Water Level Before (ft.): _____ Drilling Co.: _____
 Date Installed: _____ Static Water Level After (ft.): _____ Project Name: _____
 Date Developed: _____ Screen Length (ft.): _____ Project Number: _____
 Dev. Method: _____ Specific Capacity: _____
 Pump Type: _____ Casing ID (in.): _____

[illegible]



SOIL & SEDIMENT SAMPLE LOG SHEET

Page ___ of ___

Project Site Name: _____
Project No.: _____

- ☐ Surface Soil
☐ Subsurface Soil
☐ Sediment
☐ Other: _____
☐ QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
☐ Low Concentration
☐ High Concentration

GRAB SAMPLE DATA:

Date:	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA:

Date:	Time	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION:

Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD

Duplicate ID No.:

Signature(s):

Well I.D. #:



PROJECT NAME : _____

PROJECT NUMBER : _____

[illegible]



DAILY ACTIVITIES RECORD

PROJECT NAME:	_____	PROJECT NUMBER:	_____
CLIENT:	_____	LOCATION:	_____
DATE:	_____	ARRIVAL TIME:	_____
B&RE PERSONNEL:	_____	DEPARTURE TIME:	_____
CONTRACTOR:	_____	DRILLER:	_____

ITEM	QUANTITY ESTIMATE	QUANTITY TODAY	PREVIOUS TOTAL QUANTITY	CUMULATIVE QUANTITY TO DATE

COMMENTS: _____

APPROVED BY: _____

B&RE REPRESENTATIVE

DRILLER

DATE: _____

CERTIFICATE OF CONFORMANCE

Well Designation: _____

Site Name: _____

Date Installed: _____

Project Name: _____

Responsible Professional: _____

Drilling Company: _____

Driller: _____

Project Number: _____

Material	Brand/Description	Source/Supplier	Sample Collected ?
Well Casing			
Well Screen			
End Cap			
Drilling Fluid			
Drilling Fluid Additives			
Backfill Material			
Annular Filter Pack			
Bentonite Seal			
Annular Grout			
Surface Cement			
Protective Casing			
Paint			
Rod Lubricant			
Compressor Oil			

To the best of my knowledge, I certify that the above described materials were used during installation of this monitoring well.

Signature of Responsible Professional: _____

CHAIN OF CUSTODY RECORD

PROJECT NO.:					SITE NAME:					NO. OF CON- TAINERS						REMARKS	
SAMPLERS (SIGNATURE):																	
STATION NO.	DATE	TIME	COMP	GRAB	STATION LOCATION												
RELINQUISHED BY (SIGNATURE):				DATE / TIME:		RECEIVED BY(SIGNATURE):				RELINQUISHED BY (SIGNATURE):				DATE / TIME:		RECEIVED BY(SIGNATURE):	
RELINQUISHED BY (SIGNATURE):				DATE / TIME:		RECEIVED BY (SIGNATURE):				RELINQUISHED BY (SIGNATURE):				DATE / TIME:		RECEIVED BY(SIGNATURE):	
RELINQUISHED BY (SIGNATURE):				DATE / TIME:		RECEIVED FOR LABORATORY BY (SIGNATURE):				DATE / TIME:		REMARKS:					

APPENDIX C

B&R Environmental Standard Operating Procedures (SOPs)

GH-1.3	Soil and Rock Drilling Methods
GH-1.5	Borehole and Sample Logging
GH-2.4	In-Situ Hydraulic Conductivity Testing
GH-2.8	Groundwater Monitoring Point Installation
SA-1.1	Groundwater Sample Acquisition and Onsite Water Quality Testing
SA-1.3	Soil Sampling
SA-6.1	Non-Radiological Sample Handling
SA-6.3	Field Documentation
SA-7.1	Decontamination of Field Equipment and Waste Handling



BROWN & ROOT ENVIRONMENTAL

STANDARD OPERATING PROCEDURES

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Effective Date 03/01/96	Revision 0
Applicability B&R Environmental, NE	
Prepared Earth Sciences Department	
Approved D. Senovich <i>DS</i>	

Subject

SOIL AND ROCK DRILLING METHODS

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FIGURE

NUMBER

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1.0 PURPOSE

The purpose of this procedure is to describe the methods and equipment necessary to perform soil and rock borings and identify the equipment, sequence of events, and appropriate methods necessary to obtain soil, both surface and subsurface, and rock samples during field sampling activities.

2.0 SCOPE

This guideline addresses most of the accepted and standard drilling techniques, their benefits, and drawbacks. It should be used generally to determine what type of drilling techniques would be most successful depending on site-specific geologic conditions and the type of sampling required.

The sampling methods described within this procedure are applicable to collecting surface and subsurface soil samples, and obtaining rock core samples for lithologic and hydrogeologic evaluation, excavation/foundation design and related civil engineering purposes.

3.0 GLOSSARY

Rock Coring - A method in which a continuous solid cylindrical sample of rock or compact rock-like soil is obtained by the use of a double tube core barrel that is equipped with an appropriate diamond-studded drill bit which is advanced with a hydraulic rotary drilling machine.

Wire-Line Coring - As an alternative to conventional coring, this technique is valuable in deep hole drilling, since this method eliminates trips in and out of the hole with the coring equipment. With this technique, the core barrel becomes an integral part of the drill rod string. The drill rod serves as both a coring device and casing.

4.0 RESPONSIBILITIES

Project Manager - In consultation with the project geologist, the Project Manager is responsible for evaluating the drilling requirements for the site and specifying drilling techniques that will be successful given the study objectives and geologic conditions at the site. The Project Manager also determines the disposal methods for products generated by drilling, such as drill cuttings and well development water, as well as any specialized supplies or logistical support required for the drilling operations.

Field Operations Leader (FOL) - The FOL is responsible for the overall supervision and scheduling of drilling activities, and is strongly supported by the project geologist.

Project Geologist - The project geologist is responsible for ensuring that standard and approved drilling procedures are followed. The geologist will generate a detailed boring log for each test hole. This log shall include a description of materials, samples, method of sampling, blow counts, and other pertinent drilling and testing information that may be obtained during drilling (see SOPs SA-6.3 and GH-1.5). Often this position for inspecting the drilling operations may be filled by other geotechnical personnel, such as soils and foundation engineers, civil engineers, etc.

Determination of the exact location for borings is the responsibility of the site geologist. The final location for drilling must be properly documented on the boring log. The general area in which the borings are to be located will be shown on a site map included in the Work Plan and/or Sampling and Analysis Plan.

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Drilling Subcontractor - Operates under the supervision of the FOL. Responsible for obtaining all drilling permits and clearances, and supplying all services (including labor), equipment and material required to perform the drilling, testing, and well installation program, as well as maintenance and quality control of such required equipment except as stated in signed and approved subcontracts.

The driller must report any major technical or analytical problems encountered in the field to the FOL within 24 hours of determination, and must provide advance written notification of any changes in field procedures, describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the FOL (with the concurrence of the Project Manager).

The drilling subcontractor is responsible for following decontamination procedures specified in the project plan documents. Upon completion of the work, the driller is responsible for demobilizing all equipment, cleaning up any materials deposited on site during drilling operations, and properly backfilling any open borings.

5.0 PROCEDURES

5.1 General

The purpose of drilling boreholes is:

- To determine the type, thickness, and certain physical and chemical properties of the soil, water and rock strata which underlie the site.
- To install monitoring wells or piezometers.

All drilling and sampling equipment will be cleaned between samples and borings using appropriate decontamination procedures as outlined in SOP SA-7.1. Unless otherwise specified, it is generally advisable to drill borings at "clean" locations first, and at the most contaminated locations last, to reduce the risk of spreading contamination between locations. All borings must be logged by the rig geologist as they proceed (see SOPs SA-6.3 and GH-1.5). Situations where logging would not be required would include installation of multiple well points within a small area, or a "second attempt" boring adjacent to a boring that could not be continued through resistant material. In the latter case, the boring log can be resumed 5 feet above the depth at which the initial boring was abandoned, although the rig geologist should still confirm that the stratigraphy at the redrilled location conforms essentially with that encountered at the original location. If significant differences are seen, each hole should be logged separately.

5.2 Drilling Methods

The selected drilling methods described below apply to drilling in subsurface materials, including, but not limited to, sand, gravel, clay, silt, cobbles, boulders, rock and man-made fill. Drilling methods should be selected after studying the site geology and terrain, the waste conditions at the site, and reviewing the purpose of drilling and the overall subsurface investigation program proposed for the site. The full range of different drilling methods applicable to the proposed program should be identified with final selection based on relative cost, availability, time constraints, and how well each method meets the sampling and testing requirements of the individual drilling program.

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5.2.1 Continuous-Flight Hollow-Stem Auger Drilling

This method of drilling consists of rotating augers with a hollow stem into the ground. Cuttings are brought to the surface by the rotating action of the auger. This method is relatively quick and inexpensive. Advantages of this type of drilling include:

- Samples can be obtained without pulling the augers out of the hole. However, this is a poor method for obtaining grab samples from thin, discrete formations because of mixing of soils which occurs as the material is brought to the surface. Sampling of such formations requires the use of split-barrel or thin-wall tube samplers advanced through the hollow core of the auger.
- No drilling fluids are required.
- A well can be installed inside the auger stem and backfilled as the augers are withdrawn.

Disadvantages and limitations of this method of drilling include:

- Augering can only be done in unconsolidated materials.
- The inside diameter of hollow stem augers used for well installation should be at least 4 inches greater than the well casing. Use of such large-diameter hollow-stem augers is more expensive than the use of small-diameter augers in boreholes not used for well installation. Furthermore, the density of unconsolidated materials and depths become more of a limiting factor. More friction is produced with the larger diameter auger and subsequently greater torque is needed to advance the boring.
- The maximum effective depth for drilling is 150 feet or less, depending on site conditions and the size of augers used.
- In augering through clean sand formations below the water table, the sand will tend to flow into the hollow stem when the plug is removed for soil sampling or well installation. If the condition of "running" or "flowing" sands is persistent at a site, an alternative method of drilling is recommended, in particular for wells or boreholes deeper than 25 feet.
- Hollow-stem auger drilling is the preferred method of drilling. Most alternative methods require the introduction of water or mud downhole (air rotary is the exception) to maintain the open borehole. With these other methods, great care must be taken to ensure that the method does not interfere with the collection of a representative sample (which is the objective of the borehole construction. With this in mind, the preferred order of choice of drilling method after hollow-stem augering (HSA) is:
 - Cable tool
 - Casing drive (air)
 - Air rotary
 - Mud rotary
 - Rotosonic
 - Drive and wash
 - Jetting

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However, the use of any method will also depend on efficiency and cost-effectiveness. In many cases, mud rotary is the only feasible alternative to hollow-stem augering. Thus, mud rotary drilling is generally acceptable as a first substitute for HSA.

The procedures for sampling soils through holes drilled by hollow-stem auger shall conform with the applicable ASTM Standards: D1587-83 and D1586-84. The guidelines established in SOP SA-1.3 shall also be followed. The hollow-stem auger may be advanced by any power-operated drilling machine having sufficient torque and ram range to rotate and force the auger to the desired depth. The machine must, however, be equipped with the accessory equipment needed to perform required sampling, or rock coring.

The hollow-stem auger may be used without the plug when boring for geotechnical examination or for well installation. However, when drilling below the water table, specially designed plugs which allow passage of formation water but not solid material shall be used (see Reference 1 of this guideline). This drilling configuration method also prevents blow back and plugging of the auger when the plug is removed for sampling.

Alternately, it may be necessary to keep the hollow stem full of water, at least to the level of the water table, to prevent blowback and plugging of the auger. If water is added to the hole, it must be sampled and analyzed to determine if it is free from contaminants prior to use. In addition, the amount of water introduced, the amount recovered upon attainment of depth, and the amount of water extracted during well development must be carefully logged in order to ensure that a representative sample of the formation water can be obtained. Well development should occur as soon after well completion as practicable (see SOP GH-2.8 for well development procedures). If gravelly or hard material is encountered which prevents advancing the auger to the desired depth, augering should be halted and either driven casing or hydraulic rotary methods should be attempted. If the depth to the bedrock/soil interface and bedrock lithology must be determined, then a 5-foot confirmatory core run should be conducted (see Section 5.2.9).

At the option of the Field Operations Leader (in communication with the Project Manager), when resistant materials prevent the advancement of the auger, a new boring can be attempted. The original boring must be properly backfilled and the new boring started a short distance away at a location determined by the site geologist. If multiple water bearing strata were encountered, the original boring must be grouted. In some formations, it may be prudent to also grout borings which penetrate only the water table aquifer, since loose soil backfill in the boring may still provide a preferred pathway for surface liquids to reach the water table.

5.2.2 Continuous-Flight Solid-Stem Auger Drilling

This drilling method is similar to hollow-stem augering. Practical application of this method is severely restricted compared to use of hollow-stem augers. Split-barrel (split-spoon) sampling cannot be performed without pulling the augers out, which may allow the hole to collapse. The continuous-flight solid-stem auger drilling method is therefore very time consuming and is not cost effective. Also, augers would have to be withdrawn before installing a monitoring well, which again, may allow the hole to collapse. Furthermore, geologic logging by examining the soils brought to the surface is unreliable, and depth to water may be difficult to determine while drilling.

There would be very few situations where use of a solid-stem auger would be preferable to other drilling methods. The only practical applications of this method would be to drill boreholes for well installation where no lithologic information is desired and the soils are such that the borehole can be expected to

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remain open after the augers are withdrawn. Alternatively, this technique can be used to find depth to bedrock in an area when no other information is required from drilling.

5.2.3 Rotary Drilling

Direct rotary drilling includes air-rotary and fluid-rotary drilling. For air or fluid-rotary drilling, the rotary drill may be advanced to the desired depth by any power-operated drilling machine having sufficient torque and rpm range to rotate and force the bit to the desired depth. The drilling machine must, however, be equipped with any accessory equipment needed to perform required sampling, or coring. Prior to sampling, any settled drill cuttings in the borehole must be removed.

Air-rotary drilling is a method of drilling where the drill rig simultaneously turns and exerts a downward pressure on the drilling rods and bit while circulating compressed air down the inside of the drill rods, around the bit, and out the annulus of the borehole. Air circulation serves to both cool the bit and remove the cuttings from the borehole. Advantages of this method include:

- The drilling rate is high (even in rock).
- The cost per foot of drilling is relatively low.
- Air-rotary rigs are common in most areas.
- No drilling fluid is required (except when water is injected to keep down dust).
- The borehole diameter is large, to allow room for proper well installation procedures.

Disadvantages to using this method include:

- Formations must be logged from the cuttings that are blown to the surface and thus the depths of materials logged are approximate.
- Air blown into the formation during drilling may "bind" the formation and impede well development and natural groundwater flow.
- In-situ samples cannot be taken, unless the hole is cased.
- Casing must generally be used in unconsolidated materials.
- Air-rotary drill rigs are large and heavy.

A variation of the typical air-rotary drill bit is a down hole hammer which hammers the drill bit down as it drills. This makes drilling in hard rock faster. Air-rotary drills can also be adapted to use for rock coring although they are generally slower than other types of core drills. A major application of the air-rotary drilling method would be to drill holes in rock for well installation.

Fluid-Rotary drilling operates in a similar manner to air-rotary drilling except that a drilling fluid ("mud") or clean water is used in place of air to cool the drill bit and remove cuttings. There are a variety of fluids that can be used with this drilling method, including bentonite slurry and synthetic slurries. If a drilling fluid other than water/cuttings is used, it must be a natural clay (i.e., bentonite) and a "background" sample of the fluid should be taken for analysis of possible organic or inorganic contaminants.

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Advantages to the fluid-rotary drilling method include:

- The ability to drill in many types of formations.
- Relatively quick and inexpensive.
- Split-barrel (split-spoon) or thin-wall (Shelby) tube samples can be obtained without removing drill rods if the appropriate size drill rods and bits (i.e., fish-tail or drag bit) are used.
- In some borings temporary casing may not be needed as the drilling fluids may keep the borehole open.
- Drill rigs are readily available in most areas.

Disadvantages to this method include:

- Formation logging is not as accurate as with hollow-stem auger method if split-barrel (split-spoon) samples are not taken (i.e., the depths of materials logged from cuttings delivered to the surface are approximate).
- Drilling fluids reduce permeability of the formation adjacent to the boring to some degree, and require more extensive well development than "dry" techniques (augering, air-rotary).
- No information on depth to water is obtainable while drilling.
- Fluids are needed for drilling, and there is some question about the effects of the drilling fluids on subsequent water samples obtained. For this reason as well, extensive well development may be required.
- In very porous materials (i.e., rubble fill, boulders, coarse gravel) drilling fluids may be continuously lost into the formation. This requires either constant replenishment of the drilling fluid, or the use of casing through this formation.
- Drill rigs are large and heavy, and must be supported with supplied water.
- Groundwater samples can be potentially diluted with drilling fluid.

The procedures for performing direct rotary soil investigations and sampling shall conform with the applicable ASTM standards: D2113-83, D1587-83, and D1586-84.

Soil samples shall be taken as specified by project plan documents, or more frequently, if requested by the project geologist. Any required sampling shall be performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool.

When field conditions prevent the advancement of the hole to the desired depth, a new boring may be drilled at the request of the Field Operations Leader. The original boring shall be backfilled using methods and materials appropriate for the given site and a new boring started a short distance away at a location determined by the project geologist.

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5.2.4 Rotosonic Drilling

The Rotosonic drilling method employs a high frequency vibrational and low speed rotational motion coupled with down pressure to advance the cutting edge of a drill string. This produces a uniform borehole while providing a continuous, undisturbed core sample of both unconsolidated and most bedrock formations. Rotosonic drilling advances a 4-inch diameter to 12-inch diameter core barrel for sampling and can advance up to a 12-inch diameter outer casing for the construction of standard and telescoped monitoring wells. During drilling, the core barrel is advanced ahead of the outer barrel in increments as determined by the site geologist and depending upon type of material, degree of subsurface contamination and sampling objectives.

The outer casing can be advanced at the same time as the inner drill string and core barrel, or advanced down over the inner drill rods and core barrel, or after the core barrel has moved ahead to collect the undisturbed sample and has been pulled out of the borehole. The outer casing can be advanced dry in most cases, or can be advanced with water or air depending upon the formations being drilled, the depth and diameter of the hole, or requirements of the project.

Advantages of this method include:

- Sampling and well installation are faster as compared to other drilling methods.
- Continuous sampling, with larger sample volume as compared to split-spoon sampling.
- The ability to drill through difficult formations such as cobbles or boulders, hard till and bedrock.
- Reduction of IDW by an average of 70 to 80 percent.
- Well installations are quick and controlled by elimination of potential bridging of annular materials during well installation, due to the ability to vibrate the outer casing during removal.

Disadvantages include:

- The cost for Rotosonic drilling as compared to other methods are generally higher. However, the net result can be a significant savings considering reduced IDW and shortened project duration.
- Rotosonic drill rigs are large and need ample room to drill, however, Rotosonic units can be placed on the ground or placed on an ATV.
- There are a limited number of Rotosonic drilling contractors at the present time.

5.2.5 Reverse Circulation Rotary Drilling

The common reverse-circulation rig is a water or mud-rotary rig with a large-diameter drill pipe which circulates the drilling water down the annulus and up the inside of the drill pipe (reverse flow direction from direct mud-rotary). This type of rig is used for the construction of large-capacity production water wells and is not suited for small, water quality sampling wells because of the use of drilling muds and the large-diameter hole which is created. A few special reverse-circulation rotary rigs are made with double-wall drill pipe. The drilling water or air is circulated down the annulus between the drill pipes and up inside the inner pipe.

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Advantages of the latter method include:

- The formation water is not contaminated by the drilling water.
- Formation samples can be obtained, from known depths.
- When drilling with air, immediate information is available regarding the water-bearing properties of formations penetrated.
- Collapsing of the hole in unconsolidated formations is not as great a problem as when drilling with the normal air-rotary rig.

Disadvantages include:

- Double-wall, reverse-circulation drill rigs are very rare and expensive to operate.
- Placing cement grout around the outside of the well casing above a well screen often is difficult, especially when the screen and casing are placed down through the inner drill pipe before the drill pipe is pulled out.

5.2.6 Drill-through Casing Driver

The driven-casing method consists of alternately driving casing (fitted with a sharp, hardened casing shoe) into the ground using a hammer lifted and dropped by the drill rig (or an air-hammer) and cleaning out the casing using a rotary chopping bit and air or water to flush out the materials. The casing is driven down in stages (usually 5 feet per stage); a continuous record is kept of the blows per foot in driving the casing (see SOP GH-1.5). The casing is normally advanced by a 300-pound hammer falling freely through a height of 30 inches. Simultaneous washing and driving of the casing is not recommended. If this procedure is used, the elevations within which wash water is used and in which the casing is driven must be clearly recorded.

The driven casing method is used in unconsolidated formations only. When the boring is to be used for later well installation, the driven casing used should be at least 4 inches larger in diameter than the well casing to be installed. Advantages to this method of drilling include:

- Split-barrel (split-spoon) sampling can be conducted while drilling.
- Well installation is easily accomplished.
- Drill rigs used are relatively small and mobile.
- The use of casing minimizes flow into the hole from upper water-bearing layers; therefore, multiple aquifers can be penetrated and sampled for rough field determinations of some water quality parameters.

Some of the disadvantages include:

- This method can only be used in unconsolidated formations.
- The method is slower than other methods (average drilling progress is 30 to 50 feet per day).

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- Maximum depth of the borehole varies with the size of the drill rig and casing diameter used, and the nature of the formations drilled.
- The cost per hour or per foot of drilling may be substantially higher than other drilling methods.
- It is difficult and time consuming to pull back the casing if it has been driven very deep (deeper than 50 feet in many formations).

5.2.7 Cable Tool Drilling

A cable tool rig uses a heavy, solid-steel, chisel-type drill bit ("tool") suspended on a steel cable, which when raised and dropped, chisels or pounds a hole through the soils and rock. Drilling progress may be expedited by the use of "slip-jars" which serve as a cable-activated down hole percussion device to hammer the bit ahead.

When drilling through the unsaturated zone, some water must be added to the hole. The cuttings are suspended in the water and then bailed out periodically. Below the water table, after sufficient ground water enters the borehole to replace the water removed by bailing, no further water needs to be added.

When soft caving formations are encountered, it is usually necessary to drive casing as the hole is advanced to prevent collapse of the hole. Often the drilling can be only a few feet below the bottom of the casing. Because the drill bit is lowered through the casing, the hole created by the bit is smaller than the casing. Therefore, the casing (with a sharp, hardened casing shoe on the bottom) must be driven into the hole (see Section 5.2.5 of this guideline).

Advantages of the cable-tool method include the following:

- Information regarding water-bearing zones is readily available during the drilling. Even relative permeabilities and rough water quality data from different zones penetrated can be obtained by skilled operators.
- The cable-tool rig can operate satisfactorily in all formations, but is best suited for caving, boulder, cable or coarse gravel type formations (e.g., glacial till) or formations with large cavities above the water table (such as limestones).
- When casing is used, the casing seals formation water out of the hole, preventing down hole contamination and allowing sampling of deeper aquifers for field-measurable water quality parameters.
- Split-barrel (split-spoon) or thin-wall (Shelby) tube samples can be collected through the casing.

Disadvantages include:

- Drilling is slow compared with rotary rigs.
- The necessity of driving the casing in unconsolidated formations requires that the casing be pulled back if exposure of selected water-bearing zones is desired. This process complicates the well completion process and often increases costs. There is also a chance that the casing may become stuck in the hole.

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- The relatively large diameters required (minimum of 4-inch casing) plus the cost of steel casing result in higher costs compared to rotary drilling methods where casing is not required (e.g., such use of a hollow-stem auger).
- Cable-tool rigs have largely been replaced by rotary rigs. In some parts of the U.S., availability may be difficult.

5.2.8 Jet Drilling (Washing)

Jet drilling, which should be used only for piezometer or vadose zone sampler installation, consists of pumping water or drilling mud down through a small diameter (1/2- to 2-inch) standard pipe (steel or PVC). The pipe may be fitted with a chisel bit or a special jetting screen. Formation materials dislodged by the bit and jetting action of the water are brought to the surface through the annulus around the pipe. As the pipe is jetted deeper, additional lengths of pipe may be added at the surface.

Jet percussion is a variation of the jetting method, in which the casing is driven with a drive weight. Normally, this method is used to place 2-inch-diameter casing in shallow, unconsolidated sand formations, but this method has also been used to install 3- to 4-inch-diameter casings to a depth of 200 feet.

Jetting is acceptable in very soft formations, usually for shallow sampling, and when introduction of drilling water to the formation is acceptable. Such conditions would occur during rough stratigraphic investigation or installation of piezometers for water level measurement. Advantages of this method include:

- Jetting is fast and inexpensive.
- Because of the small amount of equipment required, jetting can be accomplished in locations where access by a normal drilling rig would be very difficult. For example, it would be possible to jet down a well point in the center of a lagoon at a fraction of the cost of using a drill rig.
- Jetting numerous well points just into a shallow water table is an inexpensive method for determining the water table contours, hence flow direction.

Disadvantages include the following:

- A large amount of foreign water or drilling mud is introduced above and into the formation to be sampled.
- Jetting is usually done in very soft formations which are subject to caving. Because of this caving, it is often not possible to place a grout seal above the screen to assure that water in the well is only from the screened interval.
- The diameter of the casing is usually limited to 2 inches; therefore, samples must be obtained by methods applicable to small diameter casings.
- Jetting is only possible in very soft formations that do not contain boulders or coarse gravel, and the depth limitation is shallow (about 30 feet without jet percussion equipment).
- Large quantities of water are often needed.

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5.2.9 Drilling with a Hand Auger

This method is applicable wherever the formation, total depth of sampling, and the site and groundwater conditions are such as to allow hand auger drilling. Hand augering can also be considered at locations where drill rig access is not possible. All hand auger borings will be performed according to ASTM D1452-80.

Samples should be taken continuously unless otherwise specified by the project plan documents. Any required sampling is performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. Typical equipment used for sampling and advancing shallow "hand auger" holes are Iwan samplers (which are rotated) or post hole diggers (which are operated like tongs). These techniques are slow but effective where larger pieces of equipment do not have access, and where very shallow holes are desired (less than 15 feet). Surficial soils must be composed of relatively soft and non-cemented formations to allow penetration by the auger.

5.2.10 Rock Drilling and Coring

When soil borings cannot be continued using augers or rotary methods due to the hardness of the soil or when rock or large boulders are encountered, drilling and sampling can be performed using a diamond bit corer in accordance with ASTM D2113.

Drilling is done by rotating and applying downward pressure to the drill rods and drill bit. The drill bit is a circular, hollow, diamond-studded bit attached to the outer core barrel in a double-tube core barrel. The use of single-tube core barrels is not recommended, as the rotation of the barrel erodes the sample and limits its use for detailed geological evaluation. Water or air is circulated down through the drill rods and annular space between the core barrel tubes to cool the bit and remove the cuttings. The bit cuts a core out of the rock which rises into an inner barrel mounted inside the outer barrel. The inner core barrel and rock core are removed by lowering a wire line with a coupling into the drill rods, latching onto the inner barrel and withdrawing the inner barrel. A less efficient variation of this method utilizes a core barrel that cannot be removed without pulling all of the drill rods. This variation is practical only if less than 50 feet of core is required.

Core borings are made through the casing used for the soil borings. The casing must be driven and sealed into the rock formation to prevent seepage from the overburden into the hole to be cored (see Section 5.3 of this guideline). A double-tube core barrel with a diamond bit and reaming shell or equivalent should be used to recover rock cores of a size specified in the project plans. The most common core barrel diameters are listed in Attachment A.

Soft or decomposed rock should be sampled with a driven split-barrel whenever possible or cored with a Denison or Pitcher sampler.

When coring rock, including shale and claystone, the speed of the drill and the drilling pressure, amount and pressure of water, and length of run can be varied to give the maximum recovery from the rock being drilled. Should any rock formation be so soft or broken that the pieces continually fall into the hole causing unsatisfactory coring, the hole should be reamed and a flush-joint casing installed to a point below the broken formation. The size of the flush-joint casing must permit securing the core size specified. When soft or broken rock is anticipated, the length of core runs should be reduced to less than 5 feet to avoid core loss and minimize core disturbance.

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Advantages of core drilling include:

- Undisturbed rock cores can be recovered for examination and/or testing.
- In formations in which the cored hole will remain open without casing, water from the rock fractures may be recovered from the well without the installation of a well screen and gravel pack.
- Formation logging is extremely accurate.
- Drill rigs are relatively small and mobile.

Disadvantages include:

- Water or air is needed for drilling.
- Coring is slower than rotary drilling (and more expensive).
- Depth to water cannot accurately be determined if water is used for drilling.
- The size of the borehole is limited.

This drilling method is useful if accurate determinations of rock lithology are desired or if open wells are to be installed into bedrock. To install larger diameter wells in coreholes, the hole must be reamed out to the proper size after boring, using air or mud rotary drilling methods.

5.2.11 Drilling & Support Vehicles

In addition to the drilling method required to accomplish the objectives of the field program, the type of vehicle carrying the drill rig and/or support equipment and its suitability for the site terrain, will often be an additional deciding factor in planning the drilling program. The types of vehicles available are extensive, and depend upon the particular drilling subcontractor's fleet. Most large drilling subcontractors will have a wide variety of vehicle and drill types suited for most drilling assignments in their particular region, while smaller drilling subcontractors will usually have a fleet of much more limited diversity. The weight, size, and means of locomotion (tires, tracks, etc.) of the drill rig must be selected to be compatible with the site terrain to assure adequate mobility between borehole locations. Such considerations also apply to necessary support vehicles used to transport water and/or drilling materials to the drill rigs at the borehole locations. When the drill rigs or support vehicles do not have adequate mobility to easily traverse the site, provisions must be made for assisting equipment, such as bulldozers, winches, timber planking, etc., to maintain adequate progress during the drilling program.

Some of the typical vehicles which are usually available for drill rigs and support equipment are:

- Totally portable drilling/sampling equipment, where all necessary components (tripods, samplers, hammers, catheads, etc.) may be hand carried to the borehole site. Drilling/sampling methods used with such equipment include:
 - Hand augers and lightweight motorized augers.
 - Retractable plug samplers--driven by hand (hammer).

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- Motorized cathead - a lightweight aluminum tripod with a small gas-engine cathead mounted on one leg, used to install small-diameter cased borings. This rig is sometimes called a "monkey on a stick."
- Skid-mounted drilling equipment containing a rotary drill or engine-driven cathead (to lift hammers and drill string), a pump, and a dismantled tripod. The skid is pushed, dragged, or winched (using the cathead drum) between boring locations.
- Small truck-mounted drilling equipment using a jeep, stake body or other light truck (4 to 6 wheels), upon which are mounted the drill and/or a cathead, a pump, and a tripod or small drilling derrick. On some rigs, the drill and/or a cathead are driven by a power take-off from the truck, instead of by a separate engine.
- Track-mounted drilling equipment is similar to truck-mounted rigs, except that the vehicle used has wide bulldozer tracks for traversing soft ground. Sometimes a continuous-track "all terrain vehicle" is also modified for this purpose. Some types of tracked drill rigs are called "bombardier" or "weasel" rigs.
- Heavy truck-mounted drilling equipment is mounted on tandem or dual tandem trucks to transport the drill, derrick, winches, and pumps or compressors. The drill may be provided with a separate engine or may use a power take-off from the truck engine. Large augers, hydraulic rotary and reverse circulation rotary drilling equipment are usually mounted on such heavy duty trucks. For soft-ground sites, the drilling equipment is sometimes mounted on and off the road vehicle having low pressure, very wide diameter tires and capable of floating; these vehicles are called "swamp buggy" rigs.
- Marine drilling equipment is mounted on various floating equipment for drilling borings in lakes, estuaries and other bodies of water. The floating equipment varies, and is often manufactured or customized by the drilling subcontractor to suit specific drilling requirements. Typically, the range of flotation vehicles include:
 - Barrel-float rigs - a drill rig mounted on a timber platform buoyed by empty 55-gallon drums or similar flotation units.
 - Barge-mounted drill rigs.
 - Jack-up platforms - drilling equipment mounted on a floating platform having retractable legs to support the unit on the sea or lake bed when the platform is jacked up out of the water.
 - Drill ships - for deep ocean drilling.

In addition to the mobility for the drilling equipment, similar consideration must be given for equipment to support the drilling operations. Such vehicles or floating equipment are needed to transport drill water, drilling supplies and equipment, samples, drilling personnel, etc. to and/or from various boring locations.

5.2.12 Equipment Sizes

In planning subsurface exploration programs, care must be taken in specifying the various drilling components, so that they will fit properly in the boring or well.

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For drilling open boreholes using rotary drilling equipment, tri-cone drill bits are employed with air, water or drilling mud to remove cuttings and cool the bit. Tri-cone bits are slightly smaller than the holes they drill (i.e., 5-7/8-inch or 7-7/8-inch bits will nominally drill 6-inch and 8-inch holes, respectively).

For obtaining split-barrel samples of a formation, samplers are commonly manufactured in sizes ranging from 2 inches to 3-1/2 inches in outside diameter. However, the most commonly used size is the 2-inch O.D., 1-3/8-inch I.D. split-barrel sampler. When this sampler is used and driven by a 140-pound (\pm 2-pound) hammer dropping 30 inches (\pm 1 inch), the procedure is called a Standard Penetration Test, and the blows per foot required to advance the sampler into the formation can be correlated to the formation's density or strength.

In planning the drilling of boreholes using hollow-stem augers or casing, in which thin-wall tube samples or diamond core drilling will be performed, refer to the various sizes and clearances provided in Attachment A of this guideline. Sizes selected must be stated in the project plan documents.

5.2.13 Estimated Drilling Progress

To estimate the anticipated rates of drilling progress for a site, the following must be considered:

- The speed of the drilling method employed.
- Applicable site conditions (e.g., terrain, mobility between borings, difficult drilling conditions in bouldery soils, rubble fill or broken rock, etc.).
- Project-imposed restrictions (e.g., drilling while wearing personal protective equipment, decontamination of drilling equipment, etc.).

Based on recent experience in drilling average soil conditions (no boulders) and taking samples at 5-foot intervals, for moderate depth (30 feet to 50 feet) boreholes (not including installation or development of wells), the following daily rates of total drilling progress may be anticipated for the following drilling methods:

Drilling Method	Average Daily Progress (linear feet)
Hollow-stem augers	75'
Solid-stem augers	50'
Mud-Rotary Drilling	100' (cuttings samples)
Rotosonic Drilling	100'-160' (continuous core)
Reverse-Circulation Rotary	100' (cuttings samples)
Skid-Rig with driven casing	30'
Rotary with driven casing	50'
Cable Tool	30'
Hand Auger	Varies
Continuous Rock Coring	50'

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5.3 Prevention of Cross-Contamination

A telescoping or multiple casing technique minimizes the potential for the migration of contaminated groundwater to lower strata below a confining layer. The telescoping technique consists of drilling to a confining layer utilizing a spun casing method with a diamond cutting or augering shoe (a method similar to the rock coring method described in Section 5.2.10, except that larger casing is used) or by using a driven-casing method (see Section 5.2.6 of this guideline) and installing a specified diameter steel well casing. The operation consists of three separate steps. Initially, a drilling casing (usually of 8-inch diameter) is installed followed by installation of the well casing (6-inch-diameter is common for 2-inch wells). This well casing is driven into the confining layer to ensure a tight seal at the bottom of the hole. The well casing is sealed at the bottom with a bentonite-cement slurry. The remaining depth of the boring is drilled utilizing a narrower diameter spun or driven casing technique within the outer well casing. A smaller diameter well casing with an appropriate length of slotted screen on the lower end, is installed to the surface.

Clean sand is placed in the annulus around and to a point of about 2 feet above the screen prior to withdrawal of the drilling casing. The annular space above the screen and to a point 2 feet above the bottom of the outer well casing is sealed with a tremied cement-bentonite slurry which is pressure-grouted or displacement-grouted into the hole. The remaining casing annulus is backfilled with clean material and grouted at the surface, or it is grouted all the way to the surface.

5.4 Cleanout of Casing Prior to Sampling

The boring hole must be completely cleaned of disturbed soil, segregated coarse material and clay adhering to the inside walls of the casing. The cleaning must extend to the bottom edge of the casing and, if possible, a short distance further (1 or 2 inches) to bypass disturbed soil resulting from the advancement of the casing. Loss of wash water during cleaning should be recorded.

For disturbed samples both above and below the water table and where introduction of relatively large volumes of wash water is permissible, the cleaning operation is usually performed by washing the material out of the casing with water; however, the cleaning should never be accomplished with a strong, downward-directed jet which will disturb the underlying soil. When clean out has reached the bottom of the casing or slightly below (as specified above), the string of tools should be lifted one foot off the bottom with the water still flowing, until the wash water coming out of the casing is clear of granular soil particles. In formations where the cuttings contain gravel and other larger particles, it is often useful to repeatedly raise and lower the drill rods and wash bit while washing out the hole, to surge these large particles upward out of the hole. As a time saver, the drilling contractor may be permitted to use a split-barrel (split-spoon) sampler with the ball check valve removed as the clean-out tool, provided the material below the spoon is not disturbed and the shoe of the spoon is not damaged. However, because the ball check valve has been removed, in some formations it may be necessary to install a flap valve or spring sample retainer in the split-spoon bit, to prevent the sample from falling out as the sampler is withdrawn from the hole. The use of jet-type chopping bits is discouraged except where large boulders and cobbles or hard-cemented soils are encountered. If water markedly softens the soils above the water table, clean out should be performed dry with an auger.

For undisturbed samples below the water table, or where wash water must be minimized, clean out is usually accomplished with an appropriate diameter clean out auger. This auger has cutting blades at the bottom to carry loose material up into the auger, and up-turned water jets just above the cutting blades to carry the removed soil to the surface. In this manner, there is a minimum of disturbance at the top of the material to be sampled. If any gravel material washes down into the casing and cannot be removed by the clean out auger, a split-barrel sample can be taken to remove it; bailers and

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sandpumps should not be used. For undisturbed samples above the groundwater table, all operations must be performed in a dry manner.

If all of the cuttings created by drilling through the overlying formations are not cleaned from the borehole prior to sampling, some of the problems which may be encountered during sampling include:

- When sampling is attempted through the cuttings remaining in the borehole, all or part of the sampler may become filled with the cuttings. This limits the amount of sample from the underlying formation which can enter and be retained in the sampler, and also raises questions as to the validity of the sample.
- If the cuttings remaining in the borehole contain coarse gravel and/or other large particles, these may block the bit of the sampler and prevent any materials from the underlying formation from entering the sampler when the sampler is advanced.
- In cased borings, should sampling be attempted through cuttings which remain in the lower portion of the casing, these cuttings could cause the sampler to become bound into the casing, such that it becomes very difficult to either advance or retract the sampler.
- When sampler blow counts are used to estimate the density or strength of the formation being sampled, the presence of cuttings in the borehole will usually give erroneously high sample blow counts.

To confirm that all cuttings have been removed from the borehole prior to attempting sampling, it is important that the rig geologist measure the "stickup" of the drill string. This is accomplished by measuring the assembled length of all drill rods and bits or samplers (the drill string) as they are lowered to the bottom of the hole, below some convenient reference point of the drill string, then measuring the height of this reference point above the ground surface. The difference of these measurements is the depth of the drill string (lower end of the bit or sampler) below the ground surface, which must then be compared with the depth of sampling required (installed depth of casing or depth of borehole drilled). If the length of drill string below grade is more than the drilled or casing depth, the borehole has been cleaned too deeply, and this deeper depth of sampling must be recorded on the log. If the length of drill string below grade is less than the drilled or casing depth, the difference represents the thickness of cuttings which remain in the borehole. In most cases, an inch or two of cuttings may be left in the borehole with little or no problem. However, if more than a few inches of cuttings are encountered, the borehole must be recleaned prior to attempting sampling.

5.5 Materials of Construction

The effects of monitoring well construction materials on specific chemical analytical parameters are described and/or referenced in SOP GH-2.8. However, there are several materials used during drilling, particularly drilling fluids and lubricants, which must be used with care to avoid compromising the representativeness of soil and ground water samples.

The use of synthetic or organic polymer slurries is not permitted at any location where soil samples for chemical analysis are to be collected. These slurry materials could be used for installation of long-term monitoring wells, but the early time data in time series collection of ground water data may then be suspect. If synthetic or organic polymer muds are proposed for use at a given site, a complete written justification including methods and procedures for their use must be provided by the site geologist and approved by the Project Manager. The specific slurry composition and the concentration of suspected contaminants for each site must be known.

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For many drilling operations, potable water is an adequate lubricant for drill stem and drilling tool connections. However, there are instances, such as drilling in tight clayey formations or in loose gravels, when threaded couplings must be lubricated to avoid binding. In these instances, to be determined in the field by the judgment of the site geologist and noted in the site logbook, and only after approval by the Project Manager, a vegetable oil or silicone-based lubricant should be used. Petroleum based greases, etc. will not be permitted. Samples of lubricants used must be provided and analyzed for chemical parameters appropriate to the given site.

5.6 Subsurface Soil Samples

Subsurface soil samples are used to characterize subsurface stratigraphy. This characterization can indicate the potential for migration of chemical contaminants in the subsurface. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of the soil samples. Where the remedial activities may include in-situ treatment or excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Engineering and physical properties of soil may also be of interest should site construction activities be planned. Soil types, grain size distribution, shear strength, compressibility, permeability, plasticity, unit weight, and moisture content are some of the physical characteristics that may be determined for soil samples.

Penetration tests are also described in this procedure. The tests can be used to estimate various physical and engineering parameters such as relative density, unconfined compressive strength, and consolidation characteristics of soils.

Surface protocols for various soil sampling techniques are discussed in SOP SA-1.3. Continuous-core soil sampling and rock coring are discussed below. The procedures described here are representative of a larger number of possible drilling and sampling techniques. The choice of techniques is based on a large number of variables such as cost, local geology, etc. The final choice of methods must be made with the assistance of drilling subcontractors familiar with the local geologic conditions. Alternative techniques must be based upon the underlying principles of quality assurance implicit in the following procedures.

The CME continuous sample tube system provides a method of sampling soil continuously during hollow-stem augering. The 5-foot sample barrel fits within the lead auger of a hollow-auger column. The sampling system can be used with a wide range of I.D. hollow-stem augers (from 3-1/4-inch to 8-1/4-inch I.D.). This method has been used to sample many different materials such as glacial drift, hard clays and shales, mine tailings, etc. This method is particularly used when SPT samples are not required and a large volume of material is needed. Also, this method is useful when a visual description of the subsurface lithology is required. Rotasonic drilling methods also provide a continuous soil sample.

5.7 Rock Sampling (Coring) (ASTM D2113-83)

Rock coring enables a detailed assessment of borehole conditions to be made, showing precisely all lithologic changes and characteristics. Because coring is an expensive drilling method, it is commonly used for shallow studies of 500 feet or less, or for specific intervals in the drill hole that require detailed logging and/or analyzing. Rock coring can, however, proceed for thousands of feet continuously, depending on the size of the drill rig, and yields better quality data than air-rotary drilling, although at a substantially reduced drilling rate. Rate of drilling varies widely, depending on the characteristics of lithologies encountered, drilling methods, depth of drilling, and condition of drilling equipment. Average

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output in a 10-hour day ranges from 40 to over 200 feet. Down hole geophysical logging or television camera monitoring is sometimes used to complement the data generated by coring.

Borehole diameter can be drilled to various sizes, depending on the information needed. Standard sizes of core barrels (showing core diameter) and casing are shown in Figure 1.

Core drilling is used when formations are too hard to be sampled by soil sampling methods and a continuous solid sample is desired. Usually, soil samples are used for overburden, and coring begins in sound bedrock. Casing is set into bedrock before coring begins to prevent loose material from entering the borehole, to prevent loss of drilling fluid, and to prevent cross-contamination of aquifers.

Drilling through bedrock is initiated by using a diamond-tipped core bit threaded to a drill rod (outer core barrel) with a rate of drilling determined by the downward pressure, rotation speed of drill rods, drilling fluid pressure in the borehole, and the characteristics of the rock (mineralogy, cementation, weathering).

5.7.1 Diamond Core Drilling

A penetration of typically less than 6 inches per 50 blows using a 140-lb. hammer dropping 30 inches with a 2-inch split-barrel sampler shall be considered an indication that soil sampling methods may not be applicable and that coring may be necessary to obtain samples.

When formations are encountered that are too hard to be sampled by soil sampling methods, the following diamond core drilling procedure may be used:

- Firmly seat a casing into the bedrock or the hard material to prevent loose materials from entering the hole and to prevent the loss of drilling fluid return. Level the surface of the rock or hard material when necessary by the use of a fishtail or other bits. If the drill hole can be retained open without the casing and if cross-contamination of aquifers in the unconsolidated materials is unlikely, leveling may be omitted.
- Begin the core drilling using a double-tube swivel-core barrel of the desired size. After drilling no more than 10 feet (3 m), remove the core barrel from the hole and take out the core. If the core blocks the flow of the drilling fluid during drilling, remove the core barrel immediately. In soft materials, a large starting size may be specified for the coring tools; where local experience indicates satisfactory core recovery or where hard, sound materials are anticipated, a smaller size or the single-tube type may be specified and longer runs may be drilled. NX/NW size coring equipment is the most commonly used size.
- When soft materials are encountered that produce less than 50 percent recovery, stop the core drilling. If soil samples are desired, secure such samples in accordance with the procedures described in ASTM Method D 1586 (Split-barrel Sampling) or in Method D 1587 (Thin-Walled Tube Sampling); sample soils per SOP SA-1.3. Resume diamond core drilling when refusal materials are again encountered.
- Since rock structures and the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described, take special care to obtain and record these features. If such broken zones or cavities prevent further advance of the boring, one of the following three steps shall be taken: (1) cement the hole; (2) ream and case; or (3) case and advance with the next smaller size core barrel, as conditions warrant.

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FIGURE 1

STANDARD SIZES OF CORE BARRELS AND CASING

Coring Bit Size	Nominal*		Set Size*	
	O.D.	I.D.	O.D.	I.D.
RWT	1 5/32	3/4	1.160	0.735
EWT	1 1/2	29/32	1.470	0.905
EX, EXL, EWG, EWM	1 1/2	13/16	1.470	0.845
AWT	1 7/8	1 9/32	1.875	1.281
AX, AXL, AWG, AWM	1 7/8	1 3/16	1.875	1.185
BWT	2 3/8	1 3/4	2.345	1.750
BX, BXL, BWG, BWM	2 3/8	1 5/8	2.345	1.655
NWT	3	2 5/16	2.965	2.313
NX, NXL, NWG, NWM	3	2 1/8	2.965	2.155
HWT	3 29/32	3 3/16	3.889	3.187
HWG	3 29/32	3	3.889	3.000
2 3/4 x 3 7/8	3 7/8	2 3/4	3.840	2.690
4 x 5 1/2	5 1/2	4	5.435	3.970
6 x 7 3/4	7 3/4	6	7.655	5.970
AX Wire line ___ ___/	1 7/8	1	1.875	1.000
BX Wire line ___ ___/	2 3/8	1 7/16	2.345	1.437
NX Wire line ___ ___/	3	1 15/16	2.965	1.937

* All dimensions are in inches; to convert to millimeters, multiply by 254.
 ___|___/ Wire line dimensions and designations may vary according to manufacturer.

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**FIGURE 1
STANDARD SIZES OF CORE BARRELS AND CASING
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Size Designations		Casing O.D., Inches	Casing Coupling		Casing bit O.D., Inches	Core barrel bit O.D., Inches*	Drill rod O.D., Inches	Approximate Core Diameter	
Casing; Casing coupling; Casing bits; Core barrel bits	Rod; rod couplings		O.D., Inches	I.D., Inches				Normal, Inches	Thinwall, Inches
RX	RW	1.437	1.437	1.188	1.485	1.160	1.094	---	0.735
EX	E	1.812	1.812	1.500	1.875	1.470	1.313	0.845	0.905
AX	A	2.250	2.250	1.906	2.345	1.875	1.625	1.185	1.281
BX	B	2.875	2.875	2.375	2.965	2.345	1.906	1.655	1.750
NX	N	3.500	3.500	3.000	3.615	2.965	2.375	2.155	2.313
HX	HW	4.500	4.500	3.938	4.625	3.890	3.500	3.000	3.187
RW	RW	1.437	Flush Joint	No Coupling	1.485	1.160	1.094	---	0.735
EW	EW	1.812			1.875	1.470	1.375	0.845	0.905
AW	AW	2.250			2.345	1.875	1.750	1.185	1.281
BW	BW	2.875			2.965	2.345	2.125	1.655	1.750
NW	NW	3.500			3.615	2.965	2.625	2.155	2.313
HW	HW	4.500			4.625	3.890	3.500	3.000	3.187
PW	---	5.500			5.650	---	---	---	---
SW	---	6.625			6.790	---	---	---	---
UW	---	7.625			7.800	---	---	---	---
ZW	---	8.625			8.810	---	---	---	---
---	AX <u> </u> <u> </u> \	---	---	---	---	1.875	1.750	1.000	---
---	BX <u> </u> <u> </u> \	---	---	---	---	2.345	2.250	1.437	---
---	NX <u> </u> <u> </u> \	---	---	---	---	2.965	2.813	1.937	---

* All dimensions are in inches; to convert to millimeters, multiply by 254.
 | / Wire line dimensions and designations may vary according to manufacturer.

**NOMINAL DIMENSIONS FOR DRILL CASINGS AND ACCESSORIES.
(DIAMOND CORE DRILL MANUFACTURERS ASSOCIATION). 288-D-2889**

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- In soft, seamy, or otherwise unsound rock, where core recovery may be difficult, M-design core barrels may be used. In hard, sound rock where a high percentage of core recovery is anticipated, the single-tube core barrel may be employed.

5.7.2 Rock Sample Preparation and Documentation

Once the rock coring has been completed and the core recovered, the rock core shall be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery as well as the rock quality designation (RQD). Each core shall be described, classified, and logged using a uniform system as presented in SOP GH-1.5. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of clay formations) or oxidation of the core, the core shall be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number, and the footage represented in each sleeve shall be included, as well as designating the top and bottom of the core run.

After sampling, rock cores shall be placed in the sequence of recovery in well-constructed wooden boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box unless accepted by the Project Geologist. The core boxes shall be constructed to accommodate at least 20 linear feet of core in rows of approximately 5 feet each and shall be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened down. Wood partitions shall be placed at the end of each core run and between rows.

The depth from the surface of the boring to the top and bottom of the drill run and run number shall be marked on the wooden partitions with indelible ink. A wooden partition (wooden block) shall be placed at the end of each run with the depth of the bottom of the run written on the block. These blocks will serve to separate successive core runs and indicate depth intervals for each run. The order of placing cores shall be the same in all core boxes. Rock core shall be placed in the box so that, when the box is open, with the inside of the lid facing the observer, the top of the cored interval contained within the box is in the upper left corner of the box, and the bottom of the cored interval is in the lower right corner of the box. The top and bottom of each core obtained and its true depth shall be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, an empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box. The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data on the box's contents. At a minimum, the following information shall be included:

- Project name.
- Project number.
- Boring number.
- Run numbers.
- Footage (depths).
- Recovery.
- RQD (%).
- Box number and total number of boxes for that boring (Example: Box 5 of 7).

For easy retrieval when core boxes are stacked, the sides and ends of the box shall also be labeled and include project number, boring number, top and bottom depths of core and box number.

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Prior to final closing of the core box, a photograph of the recovered core and the labeling on the inside cover shall be taken. If moisture content is not critical, the core shall be wetted and wiped clean for the photograph. (This will help to show true colors and bedding features in the cores).

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ATTACHMENT A
DRILLING EQUIPMENT SIZES

Drilling Component	Designation or Hole Size (Inches)	O.D. (Inches)	I.D. (Inches)	Coupling I.D. (Inches)
Hollow-stem augers (Ref. 7)	6 1/4	5	2 1/4	
	6 3/4	5 3/4	2 3/4	---
	7 1/4	6 1/4	3 1/4	---
	13 1/4	12	6	---
Thin Wall Tube Samplers (Ref. 7)	---	2	1 7/8	---
	---	2 1/2	2 3/8	---
	---	3	2 7/8	---
	---	3 1/2	3 3/8	---
	---	4 1/2	4 3/8	---
	---	5	4 3/4	---
Drill Rods (Ref. 7)	RW	1 3/32	23/32	13/32
	EW	1 3/8	15/16	7/16
	AW	1 3/4	1 1/4	5/8
	BW	2 1/8	1 3/4	3/4
	NW	2 5/8	2 1/4	1 3/8
	HW	3 1/2	3 1/16	2 3/8
	E	1 5/16	7/8	7/16
	A	1 5/8	1 1/8	9/16
	B	1 7/8	1 1/4	5/8
	N	2 3/8	2	1
				Wall Thickness (Inches)
Driven External Coupled Extra Strong Steel* Casing (Ref. 8)	2 1/2	2.875	2.323	0.276
	3	3.5	2.9	0.300
	3 1/2	4.0	3.364	0.318
	4	4.5	3.826	0.337
	5	5.63	4.813	0.375
	6	6.625	5.761	0.432
	8	8.625	7.625	0.500
	10	10.750	9.750	0.500
	12	12.750	11.750	0.500

* Add twice the casing wall thickness to casing O.D. to obtain the approximate O.D. of the external pipe couplings.

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**ATTACHMENT A
DRILLING EQUIPMENT SIZES
PAGE TWO**

Drilling Component	Designation or Hole Size (Inches)	O.D. (Inches)	I.D. (Inches)	Coupling I.D. (Inches)
Flush Coupled Casing (Ref. 7)	RX	1 7/16	1 3/16	1 3/16
	EX	1 13/16	1 5/8	1 1/2
	AX	2 1/4	2	1 29/32
	BX	2 7/8	2 9/16	2 3/8
	NX	3 1/2	3 3/16	3
	HX	4 1/2	4 1/8	3 15/16
Flush Joint Casing (Ref. 7)	RW	1 7/16	1 3/16	
	EW	1 13/16	1 1/2	
	AW	2 1/4	1 29/32	
	BW	2 7/8	2 3/8	
	NW	3 1/2	3	
	HW	4 1/2	4	
	PW	5 1/2	5	
	SW	6 5/8	6	
	UW	7 5/8	7	
	ZW	8 5/8	8	
Diamond Core Barrels (Ref. 7)	EWM	1 1/2	7/8**	
	AWM	1 7/8	1 1/8**	
	BWM	2 3/8	1 5/8**	
	NWM	3	2 1/8	
	HWG	3 7/8	3	
	2 3/4 x 3 7/8	3 7/8	2 11/16	
	4 x 5 1/2	5 1/2	3 15/16	
	6 x 7 3/4	7 3/4	5 15/16	
	AQ (wireline)	1 57/64	1 1/16**	
	BQ (wireline)	2 23/64	1 7/16**	
	NQ (wireline)	2 63/64	1 7/8	
	HQ (wireline)	3 25/32	2 1/2	

** Because of the fragile nature of the core and the difficulty to identify rock details, use of small-diameter core (1 3/8") is not recommended.



BROWN & ROOT ENVIRONMENTAL

STANDARD OPERATING PROCEDURES

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Applicability B&R Environmental, NE	
Prepared Earth Sciences Department	
Approved D. Senovich	

Subject

BOREHOLE AND SAMPLE LOGGING

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1.0 PURPOSE

The purpose of this document is to establish standard procedures and technical guidance on borehole and sample logging.

2.0 SCOPE

These procedures provide descriptions of the standard techniques for borehole and sample logging. These techniques shall be used for each boring logged to provide consistent descriptions of subsurface lithology. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer can do a good job of classification by careful, thoughtful observation and by being consistent throughout the classification procedure.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Site Geologist. Responsible for supervising all boring activities and assuring that each borehole is completely logged. If more than one rig is being used on site, the Site Geologist must make sure that each field geologist is properly trained in logging procedures. A brief review or training session may be necessary prior to the start up of the field program and/or upon completion of the first boring.

5.0 PROCEDURES

The classification of soil and rocks is one of the most important jobs of the field geologist/engineer. To maintain a consistent flow of information, it is imperative that the field geologist/engineer understand and accurately use the field classification system described in this SOP. This identification is based on visual examination and manual tests.

5.1 Materials Needed

When logging soil and rock samples, the geologist or engineer may be equipped with the following:

- Rock hammer
- Knife
- Camera
- Dilute hydrochloric acid (HCl)
- Ruler (marked in tenths and hundredths of feet)
- Hand Lens

5.2 Classification of Soils

All data shall be written directly on the boring log (Figure 1) or in a field notebook if more space is needed. Details on filling out the boring log are discussed in Section 5.5.

5.2.1 USCS Classification

Soils are to be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Figure 1 (Continued).

FIGURE 1 (CONTINUED)

SOIL TERMS									
UNIFIED SOIL CLASSIFICATION (USCS)					FINE-GRAINED SOILS				
More Than Half of Material is Larger Than No. 200 Sieve Size					More Than Half of Material is Smaller Than No. 200 Sieve Size				
FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)		TYPICAL NAMES		GROUP SYMBOL	FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)		TYPICAL NAMES		GROUP SYMBOL
GRAVELS (50% - 100% > 4.75 mm)	CLEAN GRAVELS (Low % Fines)	SANDS (50% - 100% > 0.075 mm)	SANDS WITH FINES (High % Fines)	GROUP SYMBOL	SILTS AND CLAYS (Liquid Limit > 50)	DAY STRENGTH (Crushing Characteristics)	DILATANCY (Heave on Shaking)	TENDRINESS (Consistency at Plastic Limit)	GROUP SYMBOL
Wide range in grain size and range of sizes with some intermediate particle sizes.	Wide range in grain size and range of sizes with some intermediate particle sizes.	Predominantly one size or a range of sizes with some intermediate particle sizes.	Predominantly one size or a range of sizes with some intermediate particle sizes.	GW	Well graded sands, gravelly sand mixtures, little or no fines.	None to slight	Quick to slow	None	ML
Non-plastic fines (for identification procedures, see CL)	Non-plastic fines (for identification procedures, see ML)	Plastic fines (for identification procedures, see CL)	Plastic fines (for identification procedures, see ML)	GP	Poorly graded gravels, gravelly sand mixtures, little or no fines.	Medium to high	None to very slow	Medium	CL
Silty gravels, poorly graded gravel sand silt mixtures.	Silty gravels, poorly graded gravel sand silt mixtures.	Clayey gravels, poorly graded gravel sand silt mixtures.	Clayey gravels, poorly graded gravel sand silt mixtures.	GM	Silty sands, little or no fines.	Slight to medium	Slow	Slight	OL
Well graded sand, gravelly sands, little or no fines.	Well graded sand, gravelly sands, little or no fines.	Poorly graded sand, gravelly sands, little or no fines.	Poorly graded sand, gravelly sands, little or no fines.	GC	Silty sands, little or no fines.	Slight to medium	Slow to none	Slight to medium	MI
Poorly graded sand, gravelly sands, little or no fines.	Poorly graded sand, gravelly sands, little or no fines.	Silty sands, poorly graded sand silt mixtures.	Silty sands, poorly graded sand silt mixtures.	SW	High to very high	None	None	High	CH
Sandy silts, little or no fines.	Sandy silts, little or no fines.	Clayey silts, little or no fines.	Clayey silts, little or no fines.	SP	Medium to high	None to very slow	None to very slow	Slight to medium	OH
Silty silts, little or no fines.	Silty silts, little or no fines.	Clayey silts, little or no fines.	Clayey silts, little or no fines.	SM	Readily identified by color, odor, spongy feel and frequently by fibrous texture.				PT
Plastic silts (for identification procedures, see CL)	Plastic silts (for identification procedures, see CL)	Plastic silts (for identification procedures, see ML)	Plastic silts (for identification procedures, see ML)	SC					

Boundary classifications: Soils possessing characteristics of two groups are designated by combining group symbols. For example, GW-GC, well graded gravel sand mixture with clay binder. All sieve sizes on this chart are U.S. Standard.

DENSITY OF GRANULAR SOILS		CONSISTENCY OF COHESIVE SOILS	
DESIGNATION	STANDARD PENETRATION RESISTANCE (BLows/100)	UNICOMPRESSIVE STRENGTH (Lb/sq. ft.)	FIELD IDENTIFICATION METHODS
Very Loose	0-4	Less than 0.25	Easily penetrated several inches by fist.
Loose	5-10	0.25 to 0.50	Easily penetrated several inches by thumb.
Medium Loose	11-30	0.50 to 1.0	Can be penetrated several inches by thumb.
Dense	31-50	1.0 to 2.0	Readily indented by thumb.
Very Dense	over 50	2.0 to 4.0	Readily indented by thumbnail.
		More than 4.0	Indented with difficulty by thumbnail.

ROCK TERMS		
ROCK HARDNESS (FROM CORE SAMPLES)		ROCK BROKENNESS
Descriptive term	Screwdriver or knife effects	Descriptive term
Soft	Easily dug	Very broken
Medium Soft	Can be dug	Broken
Medium Hard	Can be scratched	Blocky
Hard	Cannot be scratched	Massive

LEGEND:

SOIL SAMPLES - TYPES S-2" Split-Barrel Sample S1-3" O.D. Undisturbed Sample 0 - Other Samples, Specify in Remarks	ROCK SAMPLES - TYPES R-M (Conventional) Core (2-1/8" O.D.) R-MQ (Wireline) Core (1-7/8" O.D.) Z - Other Core Sizes, Specify in Remarks
---	--

WATER LEVELS
 12/18 Initial level w/Date & Depth
 12/19 Stabilized level w/Date & Depth

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This method of classification identifies soil types on the basis of grain size and cohesiveness.

Fine-grained soils, or fines, are smaller than the No. 200 sieve and are of two types: silt (M) and clay (C). Some classification systems define size ranges for these soil particles, but for field classification purposes, they are identified by their respective behaviors. Organic material (O) is a common component of soil but has no size range; it is recognized by its composition. The careful study of the USCS will aid in developing the competence and consistency necessary for the classification of soils.

Coarse-grained soils shall be divided into rock fragments, sand, or gravel. The terms sand and gravel not only refer to the size of the soil particles but also to their depositional history. To insure accuracy in description, the term rock fragments shall be used to indicate angular granular materials resulting from the breakup of rock. The sharp edges typically observed indicate little or no transport from their source area, and therefore the term provides additional information in reconstructing the depositional environment of the soils encountered. When the term "rock fragments" is used it shall be followed by a size designation such as "(1/4 inch Φ -1/2 inch Φ)" or "coarse-sand size" either immediately after the entry or in the remarks column. The USCS classification would not be affected by this variation in terms.

5.2.2 Color

Soil colors shall be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light gray" or "blue-gray." Since color can be utilized in correlating units between sampling locations, it is important for color descriptions to be consistent from one boring to another.

Colors must be described while the sample is still moist. Soil samples shall be broken or split vertically to describe colors. Samplers tend to smear the sample surface creating color variations between the sample interior and exterior.

The term "mottled" shall be used to indicate soils irregularly marked with spots of different colors. Mottling in soils usually indicates poor aeration and lack of good drainage.

Soil Color Charts shall not be used unless specified by the project manager.

5.2.3 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the geologist is to first identify the soil type. Granular soils contain predominantly sands and gravels. They are noncohesive (particles do not adhere well when compressed). Finer-grained soils (silts and clays) are cohesive (particles will adhere together when compressed).

The density of noncohesive, granular soils is classified according to standard penetration resistances obtained from split-barrel sampling performed according to the methods detailed in Standard Operating Procedures GH-1.3 and SA-1.3. Those designations are:

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Designation	Standard Penetration Resistance (Blows per Foot)
Very loose	0 to 4
Loose	5 to 10
Medium dense	11 to 30
Dense	31 to 50
Very dense	Over 50

Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a 2-inch outside diameter 12 inches into the material using a 140-pound hammer falling freely through 30 inches. The sampler is driven through an 18-inch sample interval, and the number of blows is recorded for each 6-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of each sample interval. It is important to note that if gravel or rock fragments are broken by the sampler or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This shall be noted on the log and referenced to the sample number. Granular soils are given the USCS classifications GW, GP, GM, SW, SP, SM, GC, or SC (see Figure 1).

The consistency of cohesive soils is determined by performing field tests and identifying the consistency as shown in Figure 2.

Cohesive soils are given the USCS classifications ML, MH, CL, CH, OL, or OH (see Figure 1).

The consistency of cohesive soils is determined either by blow counts, a pocket penetrometer (values listed in the table as Unconfined Compressive Strength), or by hand by determining the resistance to penetration by the thumb. The pocket penetrometer and thumb determination methods are conducted on a selected sample of the soil, preferably the lowest 0.5 foot of the sample in the split-barrel sampler. The sample shall be broken in half and the thumb or penetrometer pushed into the end of the sample to determine the consistency. Do not determine consistency by attempting to penetrate a rock fragment. If the sample is decomposed rock, it is classified as a soft decomposed rock rather than a hard soil. Consistency shall not be determined solely by blow counts. One of the other methods shall be used in conjunction with it. The designations used to describe the consistency of cohesive soils are shown in Figure 2.

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FIGURE 2
CONSISTENCY FOR COHESIVE SOILS

Consistency	Standard Penetration Resistance (Blows per Foot)	Unconfined Compressive Strength (Tons/Sq. Foot by pocket penetration)	Field Identification
Very soft	0 to 2	Less than 0.25	Easily penetrated several inches by fist
Soft	2 to 4	0.25 to 0.50	Easily penetrated several inches by thumb
Medium stiff	4 to 8	0.50 to 1.0	Can be penetrated several inches by thumb with moderate effort
Stiff	8 to 15	1.0 to 2.0	Readily indented by thumb but penetrated only with great effort
Very stiff	15 to 30	2.0 to 4.0	Readily indented by thumbnail
Hard	Over 30	More than 4.0	Indented with difficulty by thumbnail

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5.2.4 Weight Percentages

In nature, soils are comprised of particles of varying size and shape, and are combinations of the various grain types. The following terms are useful in the description of soil:

Terms of Identifying Proportion of the Component	Defining Range of Percentages by Weight
Trace	0 - 10 percent
Some	11 - 30 percent
Adjective form of the soil type (e.g., "sandy")	31 - 50 percent

Examples:

- Silty fine sand: 50 to 69 percent fine sand, 31 to 50 percent silt.
- Medium to coarse sand, some silt: 70 to 80 percent medium to coarse sand, 11 to 30 percent silt.
- Fine sandy silt, trace clay: 50 to 68 percent silt, 31 to 49 percent fine sand, 1 to 10 percent clay.
- Clayey silt, some coarse sand: 70 to 89 percent clayey silt, 11 to 30 percent coarse sand.

5.2.5 Moisture

Moisture content is estimated in the field according to four categories: dry, moist, wet, and saturated. In dry soil, there appears to be little or no water. Saturated samples obviously have all the water they can hold. Moist and wet classifications are somewhat subjective and often are determined by the individual's judgment. A suggested parameter for this would be calling a soil wet if rolling it in the hand or on a porous surface liberates water, i.e., dirties or muddies the surface. Whatever method is adopted for describing moisture, it is important that the method used by an individual remains consistent throughout an entire drilling job.

Laboratory tests for water content shall be performed if the natural water content is important.

5.2.6 Stratification

Stratification can only be determined after the sample barrel is opened. The stratification or bedding thickness for soil and rock is depending on grain size and composition. The classification to be used for stratification description is shown in Figure 3.

5.2.7 Texture/Fabric/Bedding

The texture/fabric/bedding of the soil shall be described. Texture is described as the relative angularity of the particles: rounded, subrounded, subangular, and angular. Fabric shall be noted as to whether the particles are flat or bulky and whether there is a particular relation between particles (i.e., all the flat particles are parallel or there is some cementation). The bedding or structure shall also be noted (e.g., stratified, lensed, nonstratified, heterogeneous varved).

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FIGURE 3

BEDDING THICKNESS CLASSIFICATION

Thickness (metric)	Thickness (Approximate English Equivalent)	Classification
> 1.0 meter	> 3.3'	Massive
30 cm - 1 meter	1.0' - 3.3'	Thick Bedded
10 cm - 30 cm	4" - 1.0'	Medium Bedded
3 cm - 10 cm	1" - 4"	Thin Bedded
1 cm - 3 cm	2/5" - 1"	Very Thin Bedded
3 mm - 1 cm	1/8" - 2/5"	Laminated
1 mm - 3 mm	1/32" - 1/8"	Thinly Laminated
< 1 mm	< 1/32"	Micro Laminated

(Weir, 1973 and Ingram, 1954)

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5.2.8 Summary of Soil Classification

In summary, soils shall be classified in a similar manner by each geologist/engineer at a project site. The hierarchy of classification is as follows:

- Density and/or consistency
- Color
- Plasticity (Optional)
- Soil types
- Moisture content
- Stratification
- Texture, fabric, bedding
- Other distinguishing features

5.3 Classification of Rocks

Rocks are grouped into three main divisions: sedimentary, igneous and metamorphic. Sedimentary rocks are by far the predominant type exposed at the earth's surface. The following basic names are applied to the types of rocks found in sedimentary sequences:

- Sandstone - Made up predominantly of granular materials ranging between 1/16 to 2 mm in diameter.
- Siltstone - Made up of granular materials less than 1/16 to 1/256 mm in diameter. Fractures irregularly. Medium thick to thick bedded.
- Claystone - Very fine-grained rock made up of clay and silt-size materials. Fractures irregularly. Very smooth to touch. Generally has irregularly spaced pitting on surface of drilled cores.
- Shale - A fissile very fine-grained rock. Fractures along bedding planes.
- Limestone - Rock made up predominantly of calcite (CaCO_3). Effervesces strongly upon the application of dilute hydrochloric acid.
- Coal - Rock consisting mainly of organic remains.
- Others - Numerous other sedimentary rock types are present in lesser amounts in the stratigraphic record. The local abundance of any of these rock types is dependent upon the depositional history of the area. Conglomerate, halite, gypsum, dolomite, anhydrite, lignite, etc. are some of the rock types found in lesser amounts.

In classifying a sedimentary rock the following hierarchy shall be noted:

- Rock type
- Color
- Bedding thickness
- Hardness
- Fracturing
- Weathering
- Other characteristics

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5.3.1 Rock Type

As described above, there are numerous types of sedimentary rocks. In most cases, a rock will be a combination of several grain types, therefore, a modifier such as a sandy siltstone, or a silty sandstone can be used. The modifier indicates that a significant portion of the rock type is composed of the modifier. Other modifiers can include carbonaceous, calcareous, siliceous, etc.

Grain size is the basis for the classification of clastic sedimentary rocks. Figure 4 is the Udden-Wentworth classification that will be assigned to sedimentary rocks. The individual boundaries are slightly different than the USCS subdivision for soil classification. For field determination of grain sizes, a scale can be used for the coarse grained rocks. For example, the division between siltstone and claystone may not be measurable in the field. The boundary shall be determined by use of a hand lens. If the grains cannot be seen with the naked eye but are distinguishable with a hand lens, the rock is a siltstone. If the grains are not distinguishable with a hand lens, the rock is a claystone.

5.3.2 Color

The color of a rock can be determined in a similar manner as for soil samples. Rock core samples shall be classified while wet, when possible, and air cored samples shall be scraped clean of cuttings prior to color classifications.

Rock color charts shall not be used unless specified by the Project Manager.

5.3.3 Bedding Thickness

The bedding thickness designations applied to soil classification (see Figure 3) will also be used for rock classification.

5.3.4 Hardness

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness is as follows:

- Soft - Weathered, considerable erosion of core, easily gouged by screwdriver, scratched by fingernail. Soft rock crushes or deforms under pressure of a pressed hammer. This term is always used for the hardness of the saprolite (decomposed rock which occupies the zone between the lowest soil horizon and firm bedrock).
- Medium soft - Slight erosion of core, slightly gouged by screwdriver, or breaks with crumbly edges from single hammer blow.
- Medium hard - No core erosion, easily scratched by screwdriver, or breaks with sharp edges from single hammer blow.
- Hard - Requires several hammer blows to break and has sharp conchoidal breaks. Cannot be scratched with screwdriver.

Note the difference in usage here of the words "scratch" and "gouge." A scratch shall be considered a slight depression in the rock (do not mistake the scraping off of rock flour from drilling with a scratch in the rock itself), while a gouge is much deeper.

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FIGURE 4

GRAIN SIZE CLASSIFICATION FOR ROCKS

Particle Name	Grain Size Diameter
Cobbles	> 64 mm
Pebbles	4 - 64 mm
Granules	2 - 4 mm
Very Coarse Sand	1 - 2 mm
Coarse Sand	0.5 - 1 mm
Medium Sand	0.25 - 0.5 mm
Fine Sand	0.125 - 0.25 mm
Very Fine Sand	0.0625 - 0.125 mm
Silt	0.0039 - 0.0625 mm

After Wentworth, 1922

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5.3.5 Fracturing

The degree of fracturing or brokenness of a rock is described by measuring the fractures or joint spacing. After eliminating drilling breaks, the average spacing is calculated and the fracturing is described by the following terms:

- Very broken (V. BR.) - Less than 2-inch spacing between fractures
- Broken (BR.) - 2-inch to 1-foot spacing between fractures
- Blocky (BL.) - 1- to 3-foot spacing between fractures
- Massive (M.) - 3 to 10-foot spacing between fractures

The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding 4 inches and dividing by the total length of the coring run, to obtain a percentage.

Method of Calculating RQD
(After Deere, 1964)

$$RQD \% = r/l \times 100$$

- r = Total length of all pieces of the lithologic unit being measured, which are greater than 4 inches length, and have resulted from natural breaks. Natural breaks include slickensides, joints, compaction slicks, bedding plane partings (not caused by drilling), friable zones, etc.
- l = Total length of the coring run.

5.3.6 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and is also useful in engineering designs. The following terms can be applied to distinguish the degree of weathering:

- Fresh - Rock shows little or no weathering effect. Fractures or joints have little or no staining and rock has a bright appearance.
- Slight - Rock has some staining which may penetrate several centimeters into the rock. Clay filling of joints may occur. Feldspar grains may show some alteration.
- Moderate - Most of the rock, with exception of quartz grains, is stained. Rock is weakened due to weathering and can be easily broken with hammer.
- Severe - All rock including quartz grains is stained. Some of the rock is weathered to the extent of becoming a soil. Rock is very weak.

5.3.7 Other Characteristics

The following items shall be included in the rock description:

- Description of contact between two rock units. These can be sharp or gradational.
- Stratification (parallel, cross stratified).

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- Description of any filled cavities or vugs.
- Cementation (calcareous, siliceous, hematitic).
- Description of any joints or open fractures.
- Observation of the presence of fossils.
- Notation of joints with depth, approximate angle to horizontal, any mineral filling or coating, and degree of weathering.

All information shown on the boring logs shall be neat to the point where it can be reproduced on a copy machine for report presentation. The data shall be kept current to provide control of the drilling program and to indicate various areas requiring special consideration and sampling.

5.3.8 Additional Terms Used in the Description of Rock

The following terms are used to further identify rocks:

- Seam - Thin (12 inches or less), probably continuous layer.
- Some - Indicates significant (15 to 40 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (70 percent) and shale (30 percent) would be "sandstone -- some shale seams."
- Few - Indicates insignificant (0 to 15 percent) amounts of the accessory material. For example, rock composed of seam of sandstone (90 percent) and shale (10 percent) would be "sandstone -- few shale seams."
- Interbedded - Used to indicate thin or very thin alternating seams of material occurring in approximately equal amounts. For example, rock composed of thin alternating seams of sandstone (50 percent) and shale (50 percent) would be "interbedded sandstone and shale."
- Interlayered - Used to indicate thick alternating seams of material occurring in approximately equal amounts.

The preceding sections describe the classification of sedimentary rocks. The following are some basic names that are applied to igneous rocks:

- Basalt - A fine-grained extrusive rock composed primarily of calcic plagioclase and pyroxene.
- Rhyolite - A fine-grained volcanic rock containing abundant quartz and orthoclase. The fine-grained equivalent of a granite.
- Granite - A coarse-grained plutonic rock consisting essentially of alkali feldspar and quartz.
- Diorite - A coarse-grained plutonic rock consisting essentially of sodic plagioclase and hornblende.
- Gabbro - A coarse-grained plutonic rock consisting of calcic plagioclase and clinopyroxene. Loosely used for any coarse-grained dark igneous rock.

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The following are some basic names that are applied to metamorphic rocks:

- Slate - A very fine-grained foliated rock possessing a well developed slaty cleavage. Contains predominantly chlorite, mica, quartz, and sericite.
- Phyllite - A fine-grained foliated rock that splits into thin flaky sheets with a silky sheen on cleavage surface.
- Schist - A medium to coarse-grained foliated rock with subparallel arrangement of the micaceous minerals which dominate its composition.
- Gneiss - A coarse-grained foliated rock with bands rich in granular and platy minerals.
- Quartzite - A fine- to coarse-grained nonfoliated rock breaking across grains, consisting essentially of quartz sand with silica cement.

5.4 Abbreviations

Abbreviations may be used in the description of a rock or soil. However, they shall be kept at a minimum. Following are some of the abbreviations that may be used:

C - Coarse	Lt - Light	Yl - Yellow
Med - Medium	BR - Broken	Or - Orange
F - Fine	BL - Blocky	SS - Sandstone
V - Very	M - Massive	Sh - Shale
Sl - Slight	Br - Brown	LS - Limestone
Occ - Occasional	Bl - Black	Fgr - Fine-grained
Tr - Trace		

5.5 Boring Logs and Documentation

This section describes in more detail the procedures to be used in completing boring logs in the field. Information obtained from the preceding sections shall be used to complete the logs. A sample boring log has been provided as Figure 5.

The field geologist/engineer shall use this example as a guide in completing each boring log. Each boring log shall be fully described by the geologist/engineer as the boring is being drilled. Every sheet contains space for 25 feet of log. Information regarding classification details is provided either on the back of the boring log or on a separate sheet, for field use.

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**FIGURE 5
COMPLETED BORING LOG (EXAMPLE)**



BORING LOG

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PROJECT NAME:	<u>NSB- SITE</u>	BORING NUMBER:	<u>SB/MW 1</u>
PROJECT NUMBER:	<u>9594</u>	DATE:	<u>3/8/96</u>
DRILLING COMPANY:	<u>SOILTEST CO.</u>	GEOLOGIST:	<u>SJ CONTI</u>
DRILLING RIG:	<u>CME-55</u>	DRILLER:	<u>R. ROCK</u>

Sample No. and Type or ROD	Depth (FL) or Run No.	Stems / 1" or ROD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/FL) or Screened Interval	MATERIAL DESCRIPTION			Remarks	PID/FID Reading (ppm)			
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification		Sample	Sampler BZ	Borehole	Driller BZ
S-1 C 0800	0.0 2.0	7 9	1.5/2.0 1.0		M DENSE	BRN TO BLK	SILTY SAND - SOME Rock Fr. - TR BRICKS (FILL)	SM MOIST SL. ORG. ODOR FILL TO 4'±	5	0	0	0
	4.0			4.0								
S-2 C 0810		5 7	2.9/2.0 2.0		M DENSE	BRN	SILTY SAND - TR FINE GRAVEL	SM MOIST - W ODOR NAT. MATL. TOOK SAMPLE 5801-0406 FOR ANALYSIS	10	0	-	-
	6.0	9 8		7.9 ±								
	8.0			8.0								
S-3 C 0820		6 8	1.9/2.0 2.0		DENSE	TAN BRN	FINE TO COARSE SAND TR. F. GRAVEL	SW WET HIT WATER = 7'±	0	0	0	0
	10.0	17 16										
	12.0			12.0								
S-4 C 0830		7 6	1.6/2.0 2.0		STIFF	GRAY	SILTY CLAY	CL MOIST - WET	0	.5	-	-
	14.0	5 8										
	15.0			15.0				AUGER REF 15'				
				16	M HARD	BRN	SILTSTONE	VER WEATHERED				
								LD & JNTS @ 15.5				
9/5 ①			4.0/5.0					WATER STAINS @ 16.5, 17.1, 17.5	0	0	0	0
				19'				LOSING SOME				
	20.0				HARD	GRAY	SANDSTONE - SOME SILTSTONE	BR DRILL H2O @ 17'± SET TEMP 6" CAS TO 15.5				
4.9/5.0 ②			5.0/5.0					SET 2"Ø PVC SCREEN 16-25	0	0	0	0
								SAND 14-25				
	25.0			25				PELLETS 12-14				

* When rock coring, enter rock brokenness.

** Include monitor reading in 5 foot intervals @ borehole. Increase reading frequency if elevated response read.

Remarks: CME-55 RIG, 4 1/4" ID HSA - 9" OD ±
2" SPLIT SPOONS - 140 LB HAMMER - 30" DROP
NX CORE IN BEDROCK RUN ① = 25 min, RUN ② = 15 min
 Converted to Well: Yes ☒ No ☐ Well I.D. #: MW-1

• 1-20Z
1-80Z

Drilling Area

Background (ppm):

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5.5.1 Soil Classification

- Identify site name, boring number, job number, etc. Elevations and water level data to be entered when surveyed data is available.
- Enter sample number (from SPT) under appropriate column. Enter depth sample was taken from (1 block = 1 foot). Fractional footages, i.e., change of lithology at 13.7 feet, shall be lined off at the proportional location between the 13- and 14-foot marks. Enter blow counts (Standard Penetration Resistance) diagonally (as shown). Standard penetration resistance is covered in Section 5.2.3.
- Determine sample recovery/sample length as shown. Measure the total length of sample recovered from the split-spoon sampler, including material in the drive shoe. Do not include cuttings or wash material that may be in the upper portion of the sample tube.
- Indicate any change in lithology by drawing a line at the appropriate depth. For example, if clayey silt was encountered from 0 to 5.5 feet and shale from 5.5 to 6.0 feet, a line shall be drawn at this increment. This information is helpful in the construction of cross-sections. As an alternative, symbols may be used to identify each change in lithology.
- The density of granular soils is obtained by adding the number of blows for the last two increments. Refer to Density of Granular Soils Chart on back of log sheet. For consistency of cohesive soils refer also to the back of log sheet - Consistency of Cohesive Soils. Enter this information under the appropriate column. Refer to Section 5.2.3.
- Enter color of the material in the appropriate column.
- Describe material using the USCS. Limit this column for sample description only. The predominate material is described last. If the primary soil is silt but has fines (clay) - use clayey silt. Limit soil descriptors to the following:
 - Trace: 0 - 10 percent
 - Some: 11 - 30 percent
 - And/Or: 31 - 50 percent
- Also indicate under Material Classification if the material is fill or natural soils. Indicate roots, organic material, etc.
- Enter USCS symbol - use chart on back of boring log as a guide. If the soils fall into one of two basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example ML/CL or SM/SP.
- The following information shall be entered under the "Remarks" column and shall include, but is not limited by, the following:
 - Moisture - estimate moisture content using the following terms - dry, moist, wet and saturated. These terms are determined by the individual. Whatever method is used to determine moisture, be consistent throughout the log.

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- Angularity - describe angularity of coarse grained particles using the terms angular, subangular, subrounded, or rounded. Refer to ASTM D 2488 or Earth Manual for criteria for these terms.
- Particle shape - flat, elongated, or flat and elongated.
- Maximum particle size or dimension.
- Water level observations.
- Reaction with HCl - none, weak, or strong.
- Additional comments:
 - Indicate presence of mica, caving of hole, when water was encountered, difficulty in drilling, loss or gain of water.
 - Indicate odor and Photoionization Detector (PID) or Flame Ionization Detector (FID) reading if applicable.
 - Indicate any change in lithology by drawing a line through the lithology change column and indicate the depth. This will help when cross-sections are subsequently constructed.
 - At the bottom of the page indicate type of rig, drilling method, hammer size and drop, and any other useful information (i.e., borehole size, casing set, changes in drilling method).
 - Vertical lines shall be drawn (as shown in Figure 5) in columns 6 to 8 from the bottom of each sample to the top of the next sample to indicate consistency of material from sample to sample, if the material is consistent. Horizontal lines shall be drawn if there is a change in lithology, then vertical lines drawn to that point.
 - Indicate screened interval of well, as needed, in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.2 Rock Classification

- Indicate depth at which coring began by drawing a line at the appropriate depth. Indicate core run depths by drawing coring run lines (as shown) under the first and fourth columns on the log sheet. Indicate RQD, core run number, RQD percent, and core recovery under the appropriate columns.
- Indicate lithology change by drawing a line at the appropriate depth as explained in Section 5.5.1.
- Rock hardness is entered under designated column using terms as described on the back of the log or as explained earlier in this section.

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- Enter color as determined while the core sample is wet; if the sample is cored by air, the core shall be scraped clean prior to describing color.
- Enter rock type based on sedimentary, igneous or metamorphic. For sedimentary rocks use terms as described in Section 5.3. Again, be consistent in classification. Use modifiers and additional terms as needed. For igneous and metamorphic rock types use terms as described in Sections 5.3.8.
- Enter brokenness of rock or degree of fracturing under the appropriate column using symbols VBR, BR, BL, or M as explained in Section 5.3.5 and as noted on the back of the Boring Log.
- The following information shall be entered under the remarks column. Items shall include but are not limited to the following:
 - Indicate depths of joints, fractures and breaks and also approximate to horizontal angle (such as high, low), i.e., 70° angle from horizontal, high angle.
 - Indicate calcareous zones, description of any cavities or vugs.
 - Indicate any loss or gain of drill water.
 - Indicate drop of drill tools or change in color of drill water.
- Remarks at the bottom of Boring Log shall include:
 - Type and size of core obtained.
 - Depth casing was set.
 - Type of rig used.
- As a final check the boring log shall include the following:
 - Vertical lines shall be drawn as explained for soil classification to indicate consistency of bedrock material.
 - If applicable, indicate screened interval in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.3 Classification of Soil and Rock from Drill Cuttings

The previous sections describe procedures for classifying soil and rock samples when cores are obtained. However, some drilling methods (air/mud rotary) may require classification and borehole logging based on identifying drill cuttings removed from the borehole. Such cuttings provide only general information on subsurface lithology. Some procedures that shall be followed when logging cuttings are:

- Obtain cutting samples at approximately 5-foot intervals, sieve the cuttings (if mud rotary drilling) to obtain a cleaner sample, place the sample into a small sample bottle or "zip lock"

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bag for future reference, and label the jar or bag (i.e. hole number, depth, date, etc.). Cuttings shall be closely examined to determine general lithology.

- Note any change in color of drilling fluid or cuttings, to estimate changes in lithology.
- Note drop or chattering of drilling tools or a change in the rate of drilling, to determine fracture locations or lithologic changes.
- Observe loss or gain of drilling fluids or air (if air rotary methods are used), to identify potential fracture zones.
- Record this and any other useful information onto the boring log as provided in Figure 1.

This logging provides a general description of subsurface lithology and adequate information can be obtained through careful observation of the drilling process. It is recommended that split-barrel and rock core sampling methods be used at selected boring locations during the field investigation to provide detailed information to supplement the less detailed data generated through borings drilled using air/mud rotary methods.

5.6 Review

Upon completion of the borings logs, copies shall be made and reviewed. Items to be reviewed include:

- Checking for consistency of all logs.
- Checking for conformance to the guideline.
- Checking to see that all information is entered in their respective columns and spaces.

6.0 REFERENCES

Unified Soil Classification System (USCS).

ASTM D2488, 1985.

Earth Manual, U.S. Department of the Interior, 1974.

7.0 RECORDS

Originals of the boring logs shall be retained in the project files.



BROWN & ROOT ENVIRONMENTAL

STANDARD OPERATING PROCEDURES

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Applicability
B&R Environmental, NE

Prepared
Earth Sciences Department

Subject

IN-SITU HYDRAULIC CONDUCTIVITY TESTING

Approved
D. Senovich

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1.0 PURPOSE

This guideline is intended to describe procedures for performing in-situ hydraulic conductivity testing (slug testing) in boreholes and monitoring wells, and provide a short description of commonly used evaluation techniques for the data generated. Slug tests are used to provide data regarding the hydraulic properties of the formation tested. A variation of the slug test, called a constant-head test, is also briefly described.

2.0 SCOPE

Slug tests are short-term tests designed to provide approximate hydraulic conductivity values for the portion of a formation immediately surrounding the screened/open interval of a well or boring. These tests are less accurate than pumping tests, as a much more localized area is involved. Therefore, a number of slug tests are performed and averaged to determine a representative hydraulic conductivity value for the formation tested. Performance of slug tests may be preferable to pumping tests in situations where handling of large volumes of contaminated water is a concern or when time/budget constraints preclude the more expensive and time-consuming setup and performance of a pumping test.

Constant-head tests also are used to determine hydraulic conductivity values and are similar to slug tests with regard to the quality of data obtained and time/cost considerations. A disadvantage of constant-head tests is that a significant volume of water may be added to the formation, potentially affecting short-term water quality.

3.0 GLOSSARY

Hydraulic Conductivity (K) - A quantitative measure of the ability of porous material to transmit water. Volume of water that will flow through a unit cross-sectional area of porous material per unit time under a head gradient. Hydraulic conductivity is dependent upon properties of the medium and fluid. Common units of expression include centimeters per second (cm/sec), feet per day (ft/day), and gallons per day per foot² (gpd/ft²).

Transmissivity (T) - A quantitative measure of the ability of an aquifer to transmit water. The product of the hydraulic conductivity times the saturated thickness.

Slug Test - A rising head or falling head test used to measure hydraulic conductivity. A slug test consists of instantaneously changing the water level within a well and measuring the rate of recovery of the water level to equilibrium conditions. Slug tests are performed by either withdrawing a slug of water (rising head test) or adding a slug of water (falling head test), then measuring recovery over time. A solid slug of known volume can be used to displace a volume of water, thereby simulating the addition or removal of water.

4.0 RESPONSIBILITIES

Project Hydrogeologist - The project hydrogeologist, in conjunction with the Project Manager, shall evaluate the type(s) and extent of hydraulic testing required for a given project during the planning process, and design the field program accordingly. The project hydrogeologist also shall ensure that field personnel have the necessary training and guidance to properly perform the tests, and shall oversee data reduction activities, including selecting the appropriate evaluation techniques and checking calculations for accuracy.

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Field Geologist - The field geologist is responsible for performing the planned field tests as specified in the project planning documents, (or approved modifications thereto). The field geologist also generally assists in the data evaluation process. The field geologist shall be knowledgeable in the testing methodologies used and is responsible for obtaining the necessary support equipment required to perform the field tests. All applicable data regarding testing procedures, equipment used, well construction, and geologic/hydrogeologic conditions shall be recorded by the field geologist. The field geologist shall be familiar enough with testing procedures/requirements to be able to recommend changes in methodology, should unanticipated field conditions be encountered.

5.0 PROCEDURES

5.1 In-situ Hydraulic Conductivity Testing in Wells

Slug tests are commonly performed in completed wells. Prior to testing, the well shall be thoroughly developed and allowed to stabilize, in order to obtain accurate results. Once the water level within the well has stabilized, it shall be quickly raised or lowered and the rate of recovery measured.

One of the basic assumptions of slug testing is that the initial change in water level is instantaneous; therefore, an effort shall be made to minimize the time involved in raising or lowering the water level initially. Various methods can be used to induce instantaneous (or nearly instantaneous) changes in water level within the well. A rise in water levels can be induced by pouring water into the well. A solid slug of known volume, quickly lowered below the water level within the well, will displace an equivalent volume of water and raise the water level within the well. The slug can be left in place until the water level restabilizes at the static water level, then suddenly removed to create a drop in water level within the well. An advantage of using a solid cylinder of known volume (slug) to change the water level is that no water is removed or added to the monitoring well. This eliminates the need to dispose of contaminated water and/or add water to the system, which might raise doubts regarding the representativeness of future groundwater samples. A bailer or pump can be used to withdraw water from the well. If a pump is used, pumping shall not continue for more than several seconds so that a cone of depression is not created which would adversely impact testing results. The pump hose shall also be removed from the well during the recovery period, as data analysis techniques involve volume of recovery versus time, and leaving the hose within the well would distort the calculated testing results by altering the apparent volume of recovery. Falling head slug tests should only be performed in wells with fully submerged screens, while rising head slug tests can be performed in wells with either partially or fully submerged screens/open intervals.

Other methods that can be used to change water levels within a well include creating a vacuum or a high pressure environment within the well. The vacuum method will raise water levels within the well, while the pressure method will depress the water level in the well. These methods are particularly useful in highly permeable formations where other methods are ineffective in creating measurable changes in water levels. Both of these methods are limited to wells which have completely submerged screens.

Rate of recovery measurements shall be obtained from time zero (maximum change in water level) until water level recovery exceeds 90 percent of the initial change in water level. In low permeability formations, the test may be cut-off short of 90 percent recovery due to time constraints. Time intervals between water level readings will vary according to the rate of recovery of the well. For a moderately fast recovering well, water level readings at 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.75, 1.0, 1.25, 1.5, 2.0, 2.5, 3.0, 4.0, . . . minutes may be required. With practice, readings at down to 0.05-minute (3 seconds) time intervals can be obtained with reasonable accuracy, using a pressure transducer and hand held readout. For wells which recover very fast, a pressure transducer and data logger may be required to obtain representative data. Time intervals between measurements can be extended for slow recovering wells.

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A typical schedule for measurements for a slow recovering well would be 0, 0.25, 0.5, 0.75, 1.0, 1.5, 2.0, 3.0, 4.0, 6.0, 8.0, 10.0, 15.0, 20.0, 30.0, . . . minutes from the beginning the test. Measurements shall be taken from the top of the well casing.

Water level measurements can be obtained using an electric water level indicator, popper, or pressure transducer. Steel tape coated with chalk or water sensitive paste although very accurate, is a slower method of obtaining water levels and is generally not recommended for use due to the frequency at which water level measurements need to be obtained during the performance of a slug test.

The following data shall be recorded when performing slug tests in wells or borings:

- Well/boring ID number
- Total depth of well/boring
- Screened/open interval depth and length
- Gravel pack interval depth and length
- Well and boring radii
- Well stickup above ground surface
- Gravel pack radius
- Static water level
- Aquifer thickness
- Depth to confining layer
- Time/recovery data
- Gravel pack porosity

A variation of the slug test, called a constant-head test, is a test in which water is added to the well at a measured rate sufficient to maintain the water level in the well at a constant height above the static water level. Once a stable elevated water level has been achieved, discharge (pumping) rate measurements are recorded in place of time/recovery data for approximately 10 to 20 minutes. The hydraulic conductivity is then calculated from this information. The constant-head test is generally not recommended for monitoring wells as large volumes of water may be introduced into the screened formation, potentially impacting later sampling events.

5.2 In-situ Hydraulic Conductivity Testing in Borings

Slug tests can be performed in borings while the boring is being advanced. This permits testing of formations at different depths throughout the drilling process. Boreholes to be tested shall be drilled using casing, so that discrete depths may be investigated. Various tests and testing methods are described below. The most appropriate test and testing method to be used in a situation varies with drilling, geologic, and general site conditions and shall be selected after a careful evaluation of the above factors.

Rising head or falling head slug tests can be performed in saturated and unsaturated formations during drilling. There are two ways that the tests can be performed. One way entails setting the casing flush with the bottom of the boring when the desired testing depth has been reached. The hole is then cleaned out to remove loose materials, the drill bit and rods are carefully withdrawn from the boring, and a few feet of sand (of higher permeability than the surrounding formation) is added to the bottom of the boring. After the water level in the boring has stabilized (for saturated formations), the static water level is measured and recorded. The water level is then raised (falling head test) or lowered (rising head test) and the change in water level is measured at time intervals determined by the field hydrogeologist. Only falling head tests can be performed for depth intervals within the unsaturated (vadose) zone. As described for wells, time intervals for water level measurements will vary according to the formation's

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hydraulic conductivity. The faster the rate of recovery expected, the shorter the time intervals between measurements shall be. A predetermined pattern of time intervals must be used during each test. The rate of change of water level will be used to calculate hydraulic conductivity. The test is to be conducted until the water level again stabilizes, or for a minimum of 20 minutes. In low permeability formations, it is not always practical to run the test until the water level stabilizes, as it may take a long time to do so. The top of the casing shall be used as the reference point for all water level measurements.

The second method for conducting a slug test during drilling consists of placing a temporary well with a short screen into the cleaned-out boring, pulling the drilling casing back to expose the screen, allowing the formation to collapse around the screen (or placing a sand/gravel pack around the screen), and performing the appropriate hydraulic conductivity test in the well, as described for the first method. Again, the test shall be conducted until the water level stabilizes or for a minimum of 20 minutes. This method allows for testing a larger section of the formation and results in more reliable hydraulic conductivity estimates.

Constant-head tests may also be performed in borings. As described for monitoring wells, once a stable elevated level has been achieved, the discharge rate into the boring is measured for a period of time, usually 10 to 20 minutes, and the hydraulic conductivity is calculated from this. This method is the most accurate method depicted in this section, and shall be given preference over others if the materials are available to perform the test and the addition of water to the boring does not adversely impact project objectives. Once the test is over, additional information can be gathered by measuring the rate of the drop in water level in the boring (for saturated formations). A limitation of the constant-head test is that foreign water is introduced into the formation which must be removed from the well area by natural or artificial means, before a representative groundwater sample can be obtained.

Detailed descriptions regarding the performance of borehole hydraulic conductivity tests and subsequent data analysis techniques are provided in Ground Water Manual (1981).

5.3 Data Analysis

There are a number of data analysis methods available to reduce and evaluate slug testing data. The determination of which method is most appropriate shall be made based on the testing conditions (including physical setup of the well/boring tested, hydrogeologic conditions, and testing methodology) and the limitations of each test analysis method. Well construction details, aquifer type (confined or unconfined), and screened/open interval (fully or partially penetrating the aquifer) shall be taken into account in selecting an analysis method. Cooper, et al. (1967), and Papadapulos, et al. (1973) have developed test interpretation procedures for fully penetrating wells in confined aquifers. Hvorslev (1951) developed a relatively simple analytical procedure for point piezometers in an infinite isotropic medium. In Cedergren (1967), Hvorslev presents a number of analytical procedures which cover a wide variety of hydrogeologic conditions, testing procedures, and well/boring/piezometer configurations. Bouwer and Rice (1976) developed an analytical technique applicable to both unconfined and confined conditions, which factors in partial/full penetration and discusses well screen gravel pack considerations. The Ground Water Manual (1981) presents a number of testing and test analysis procedures for wells and borings open above or below the water table, and for both falling head and constant-head tests. The methods described above do not represent a complete listing of test analysis methods available, but are some of the more commonly used and accepted methods. Other methods can be used, at the discretion of the project hydrogeologist and in concurrence with the Project Manager and client.

One consideration to be noted during data analysis is the determination of the screened/open interval of a tested well. If a well with a fully submerged screen is installed in a relatively low permeability formation, and a gravel pack which is significantly more permeable is installed around the screen, the

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length of the gravel pack (if longer than the screened interval) may be used as the screened/open length, rather than the screen length itself. In situations where the formation permeability is judged to be comparable to the gravel pack permeability (within about an order of magnitude) this adjustment is not required.

All data analysis applications and calculations shall be reviewed by technical personnel thoroughly familiar with testing and test analysis procedures. Upon approval of the calculations and results, the calculation sheets shall be initialed and dated by the reviewer. Distribution copies shall be supplied to appropriate project personnel and the original copy stored in the project central file.

6.0 REFERENCES

Cedergren, H. R., 1967. Seepage, Drainage, and Flow Nets. John Wiley and Sons Inc., New York, pp. 78-76.

Cooper, H. H., Jr., J. D. Bredehoeft, and I. S. Papadopoulos, 1967. Response of a Finite-Diameter Well to an Instantaneous Change of Water. Water Resources Research, V. 3, No. 1, pp. 263-269.

Hvorslev, M. J., 1951. Time Lag and Soil Permeability in Ground Water Observations. U.S. Army Corps of Engineers, Waterways Experiment Station, Washington, D.C., Bull. No. 36.

Papadopoulos, I. S., J. D. Bredehoeft, and H. H. Cooper, 1973. On the Analysis of Slug Test Data. Water Resources Research, V. 9, No. 4, pp. 1087-1089.

Bouwer, H. and R. C. Rice, 1976. "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells." Water Resources Research, 12:423-28.

United States Department of the Interior, 1981. Ground Water Manual. U.S. Government Printing Office, Denver, Colorado.

7.0 RECORDS

Field data shall be recorded on the data sheet included as Attachment A (or equivalent).¹ Any notes regarding testing procedures, problems encountered, and general observations not included on the data sheet shall be noted in the bound site logbook or field notebook. The boring log and well construction diagrams for each well/boring tested shall be used as references during testing and data analysis activities. Original data sheets shall be placed in the project file, along with the logbook/notebook.

¹ If an automated data recorder is used, the data may be displayed using the printer output from the unit. Such printouts should be annotated to include the relevant data form, or attached to the form shown as Attachment A.



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Subject

GROUNDWATER MONITORING POINT INSTALLATION

Approved
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1.0 PURPOSE

This procedure provides general guidance and information pertaining to proper monitoring well design, installation, and development.

2.0 SCOPE

This procedure is applicable to the construction of permanent monitoring wells. The methods described herein may be modified by project-specific requirements for monitoring well construction. In addition, many regulatory agencies have specific regulations pertaining to monitoring well construction and permitting. These requirements must be determined during the project planning phases of the investigation, and any required permits must be obtained before field work begins. Innovative monitoring well installation techniques, which typically are not used, will be discussed only generally in this procedure.

3.0 GLOSSARY

Monitoring Well - A well which is properly screened (if screening is necessary, e.g., open borehole), cased, and sealed which is capable of providing a groundwater level and groundwater sample representative of the zone being monitored.

Piezometer - A pipe or tube inserted into the water bearing zone, typically open to water flow at the bottom and to the atmosphere at the top, and used to measure water level elevations. Piezometers may range in size from 1/2-inch-diameter plastic tubes to well points or monitoring wells.

Potentiometric Surface - The surface representative of the level to which water will rise in a well cased to the screened aquifer.

Well Point (Drive Point) - A screened or perforated tube (Typically 1-1/4 or 2 inches in diameter) with a solid, conical, hardened point at one end, which is attached to a riser pipe and driven into the ground with a sledge hammer, drop weight, or mechanical vibrator. Well points may be used for groundwater injection and recovery, as piezometers (i.e., to measure water levels) or to provide groundwater samples for water quality data.

4.0 RESPONSIBILITIES

Driller - The driller provides adequate and operable equipment, sufficient quantities of materials, and an experienced and efficient labor force capable of performing all phases of proper monitoring well installation and construction. The driller may also be responsible for obtaining, in advance, any required permits for monitoring well installation and construction.

Rig Geologist - The rig geologist supervises and documents well installation and construction performed by the driller, and insures that well construction is adequate to provide representative groundwater data from the monitored interval. Geotechnical engineers, field technicians, or other suitable trained personnel may also serve in this capacity.

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5.0 PROCEDURES

5.1 Equipment/Items Needed

Below is a list of items that may be needed when installing a monitoring well:

- Health and safety equipment as required by the Site Safety Officer.
- Well drilling and installation equipment with associated materials (typically supplied by the driller).
- Hydrogeologic equipment (weighted engineer's tape, water level indicator, retractable engineers rule, electronic calculator, clipboard, mirror and flashlight - for observing downhole activities, paint and ink marker for marking monitoring wells, sample jars, well installation forms, and a field notebook).
- Drive point installations tools (sledge hammer, drop hammer, or mechanical vibrator; tripod, pipe wrenches, drive points, riser pipe, and end caps).

5.2 Well Design

The objectives for each monitoring well and its intended use must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, require different types of construction. During all phases of the well design, attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials to be used. The objectives for installing the monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for trace contaminants.
- Determining aquifer characteristics (e.g., hydraulic conductivity).

Siting of monitoring wells shall be performed after a preliminary estimation of the groundwater flow direction. In most cases, groundwater flow and potential well locations can be determined through the review of geologic data and the site terrain. In addition, data from production wells or other monitoring wells in the area may be used to determine the groundwater flow direction. If these methods cannot be used, piezometers, which are relatively inexpensive to install, may have to be installed in a preliminary investigative phase to determine groundwater flow direction.

5.2.1 Well Depth, Diameter, and Monitored Interval

The well depth, diameter, and monitored interval must be tailored to the specific monitoring needs of each investigation. Specification of these items generally depends on the purpose of the monitoring system and the characteristics of the hydrogeologic system being monitored. Wells of different depth, diameter, and monitored interval can be employed in the same groundwater monitoring system. For instance, varying the monitored interval in several wells, at the same location (cluster wells) can help to determine the vertical gradient and the levels at which contaminants are present. Conversely, a fully penetrating well is usually not used to quantify or vertically locate a contaminant plume, since groundwater samples collected in wells that are screened over the full thickness of the water-bearing zone will be representative of average conditions across the entire monitored interval. However, fully penetrating wells can be used to establish the existence of contamination in the water-bearing zone. The

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well diameter desired depends upon the hydraulic characteristics of the water-bearing zone, sampling requirements, drilling method and cost.

The decision concerning the monitored interval and well depth is based on the following (and possibly other) information:

- The vertical location of the contaminant source in relation to the water-bearing zone.
- The depth, thickness and uniformity of the water-bearing zone.
- The anticipated depth, thickness, and characteristics (e.g., density relative to water) of the contaminant plume.
- Fluctuation in groundwater levels (due to pumping, tidal influences, or natural recharge/discharge events).
- The presence and location of contaminants encountered during drilling.
- Whether the purpose of the installation is for determining existence or non-existence of contamination or if a particular stratigraphic zone is being investigated.
- The analysis of borehole geophysical logs.

In most situations where groundwater flow lines are horizontal, depending on the purpose of the well and the site conditions, monitored intervals are 20 feet or less. Shorter screen lengths (1 to 2 feet) are usually required where flow lines are not horizontal, (i.e., if the wells are to be used for accurate measurement of the potentiometric head at a specific point).

Many factors influence the diameter of a monitoring well. The diameter of the monitoring well depends on the application. In determining well diameter, the following needs must be considered:

- Adequate water volume for sampling.
- Drilling methodology.
- Type of sampling device to be used.
- Costs.

Standard monitoring well diameters are 2, 4, 6, or 8 inches. However, drive points are typically 1-1/4 or 2 inches in diameter. For monitoring programs which require screened monitoring wells, either a 2-inch or 4-inch-diameter well is preferred. Typically, well diameters greater than 4 inches are used in monitoring programs in which open-hole monitoring wells are required. In the smaller diameter wells, the volume of stagnant water in the well is minimized, and well construction costs are reduced, however, the type of sampling devices that can be used are limited. In specifying well diameter, sampling requirements must be considered (up to a total of 4 gallons of water may be required for a single sample to account for full organic and inorganic analyses, and split samples). The volume of water in the monitoring well available for sampling is dependent on the well diameter as follows:

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Casing Inside Diameter (Inch)	Standing Water Depth to Obtain 1 Gallon Water (Feet)	Total Depth of Standing Water for 4 Gallons (Feet)
2	6.13	25
4	1.53	6
6	0.68	3

However, if a specific well recharges quickly after purging, then well diameter may not be an important factor regarding sample volume requirements.

Pumping tests for determining aquifer characteristics may require larger diameter wells; however, in small-diameter wells in-situ permeability tests can be performed during drilling or after well installation is completed.

5.2.2 Riser Pipe and Screen Materials

Well materials are specified by diameter, type of material, and thickness of pipe. Well screens require an additional specification of slot size. Thickness of pipe is referred to as "schedule" for polyvinyl chloride (PVC) casing and is usually Schedule 40 (thinner wall) or 80 (thicker wall). Steel pipe thickness is often referred to as "Strength" and Standard Strength is usually adequate for monitoring well purposes. With larger diameter pipe, the wall thickness must be greater to maintain adequate strength. The required thickness is also dependent on the method of installation; risers for drive points require greater strength than wells installed inside drilled borings.

The selection of well screen and riser materials depends on the method of drilling, the type of subsurface materials the well penetrates, the type of contamination expected, and natural water quality and depth. Cost and the level of accuracy required are also important. The materials generally available are Teflon, stainless steel, PVC galvanized steel, and carbon steel. Each has advantages and limitations (see Attachment A of this guideline for an extensive presentation on this topic). The two most commonly used materials are PVC and stainless steel for wells in which screens are installed. Properties of these two materials are compared in Attachment B. Stainless steel is preferred where trace metals or organic sampling is required; however, costs are high. Teflon materials are extremely expensive, but are relatively inert and provide the least opportunity for water contamination due to well materials. PVC has many advantages, including low cost, excellent availability, light weight, and ease of manipulation; however, there are also some questions about organic chemical sorption and leaching that are currently being researched (see Barcelona et al., 1983). Concern about the use of PVC can be minimized if PVC wells are used strictly for geohydrologic measurements and not for chemical sampling. The crushing strength of PVC may limit the depth of installation, but Schedule 80 materials normally used for wells greater than 50 feet deep may overcome some of the problems associated with depth. However, the smaller inside diameter of Schedule 80 pipe may be an important factor when considering the size of bailers or pumps required for sampling or testing. Due to this problem, the minimum well pipe size recommended for Schedule 80 wells is 4-inch I.D.

Screens and risers may have to be decontaminated before use because oil-based preservatives and oil used during thread cutting and screen manufacturing may contaminate samples. Metal pipe, may corrode and release metal ions or chemically react with organic constituents, but this is considered by some to be less of a problem than the problem associated with PVC material. Galvanized steel is not

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recommended where samples may be collected for metal analyses, as zinc and cadmium levels in groundwater samples may become elevated from leaching of the zinc coating.

Threaded, flush-joint casing is most often preferred for monitoring well applications. PVC, Teflon, and steel can all be obtained with threaded joints at slightly more costs. Welded-joint steel casing is also acceptable. Glued PVC may release organic contaminants into the well, and therefore, should not be used if the well is to be sampled for organic constituents.

When the water-bearing zone is in consolidated bedrock, such as limestone or fractured granite, a well screen is often not necessary (the well is simply an open hole in bedrock). Unconsolidated materials, such as sands, clay, and silts require a screen. A screen slot size of 0.010 or 0.020 inch is generally used when a screen is necessary and the screened interval is artificially packed with a fine sand. The slot size controls the quantity of water entering the well and prevents entry of natural materials or sand pack. The screen shall pass no more than 10 percent of the pack material, or in-situ aquifer material. The rig geologist shall specify the combination of screen slot size and sand pack which will be compatible with the water-bearing zone, to maximize groundwater inflow and minimize head losses and movement of fines into the wells. For example, as a standard procedure, a Morie No. 1 or No. 10 to No. 20 U.S. Standard Sieve size filter pack is typically appropriate for a 0.020-inch slot screen; however, a No. 20 to No. 40 U.S. Standard Sieve size filter pack is typically appropriate for a 0.010-inch slot screen.

5.2.3 Annular Materials

Materials placed in the annular space between the borehole and riser pipe and screen include a sand pack when necessary, a bentonite seal, and cement-bentonite grout. The sand pack is usually a fine-to medium-grained poorly graded, silica sand and should relate to the grain size of the aquifer sediments. The quantity of sand placed in the annular space is dependent upon the length of the screened interval, but should always extend at least 1 foot above the top of the screen. At least 1 to 3 feet of bentonite pellets or equivalent shall be placed above the sand pack. Cement-bentonite grout (or equivalent) is then placed to extent from the top of the bentonite pellets to the ground surface.

On occasion, and with the concurrence of the involved regulatory agencies, monitoring wells may be packed naturally (i.e., no artificial sand pack installed), and the natural formation material is allowed to collapse around the well screen after the well is installed. This method has been used where the formation material itself is a relatively uniform grain size, or when artificial sand packing is not possible due to borehole collapse.

Bentonite expands by absorbing water and provides a seal between the screened interval and the overlying portion of the annular space and formation. Cement-bentonite grout is placed on top of the bentonite pellets extending to the surface. The grout effectively seals the well and eliminates the possibility for surface infiltration reaching the screened interval. Grouting also replaces material removed during drilling and prevents hole collapse and subsidence around the well. A tremie pipe should be used to introduce grout from the bottom of the hole upward, to prevent bridging, and to provide a better seal. However, in shallow boreholes that don't collapse, it may be more practical to pour the grout from the surface without a tremie pipe.

Grout is a general term which has several different connotations. For all practical purposes within the monitoring well installation industry, grout refers to the solidified material which is installed and occupies the annular space above the bentonite pellet seal. Grout, most of the time, is made up of two assemblages of material, (e.g., cement-bentonite). A cement-bentonite grout normally is a mixture of cement, bentonite, and water at a ratio of one 90-pound bag of Portland Type I cement, plus

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3 to 5 pounds of granular or flake-type bentonite, and 6 gallons of water. A neat cement consists of one ninety-pound bag of Portland Type I cement and 6 gallons of water.

In certain cases, the borehole may be drilled to a depth greater than the anticipated well installation depth. For these cases, the well shall be backfilled to the desired depth with bentonite pellets or equivalent. A short (1- to 2-foot) section of capped riser pipe sump is sometimes installed immediately below the screen, as a silt reservoir, when significant post-development silting is anticipated. This will ensure that the entire screen surface remains unobstructed.

5.2.4 Protective Casing

When the well is completed and grouted to the surface, a protective steel casing is often placed over the top of the well. This casing generally has a hinged cap and can be locked to prevent vandalism. A vent hole shall be provided in the cap to allow venting of gases and maintain atmospheric pressure as water levels rise or fall in the well. The protective casing has a larger diameter than the well and is set into the wet cement grout over the well upon completion. In addition, one hole is drilled just above the cement collar through the protective casing which acts as a weep hole for the flow of water which may enter the annulus during well development, purging, or sampling.

A protective casing which is level with the ground surface is used in roadway or parking lot applications where the top of a monitoring well must be below the pavement. The top of the riser pipe is placed 4 to 5 inches below the pavement, and a locking protective casing is cemented in place to 3 inches below the pavement. A large diameter protective sleeve is set into the wet cement around the well with the top set level with the pavement. A manhole-type lid placed over the protective sleeve. The cement should be slightly mounded to direct pooled water away from the well head.

5.3 Monitoring Well Installation

Pertinent data regarding monitoring well installation shall be recorded on log sheets as depicted and discussed in SOP SA-6.3. Attachments to this referenced SOP illustrate terms and physical construction of various types of monitoring wells.

5.3.1 Monitoring Wells in Unconsolidated Sediments

After the borehole is drilled to the desired depth, well installation can begin. The procedure for well installation will partially be dictated by the stability of the formation in which the well is being placed. If the borehole collapses immediately after the drilling tools are withdrawn, then a temporary casing must be installed and well installation will proceed through the center of the temporary casing, and continue as the temporary casing is withdrawn from the borehole. In the case of hollow-stem auger drilling, the augers will act to stabilize the borehole during well installation.

Before the screen and riser pipe are lowered into the borehole, all pipe and screen sections should be measured with an engineer's rule to ensure proper placement. When measuring sections, the threads on one end of the pipe or screen must be excluded while measuring, since the pipe and screen sections are screwed flush together.

After the screen and riser pipe are lowered through the temporary casing, the sand pack can be installed. A weighted tape measure must be used during the installation procedure to carefully monitor installation progress. The sand is poured into the annulus between the riser pipe and temporary casing, as the casing is withdrawn. Sand should always be kept within the temporary casing during withdrawal in order to ensure an adequate sand pack. However, if too much sand is within the temporary casing (greater

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than 1 foot above the bottom of the casing) bridging between the temporary casing and riser pipe may occur.

After the sand pack is installed to the desired depth (at least 1 foot above the top of the screen), then the bentonite pellet seal (or equivalent), can be installed in the same manner as the sand pack. At least 1 to 3 feet of bentonite pellets should be installed above the sand pack.

The cement-bentonite grout is then mixed and either poured or tremied into the annulus as the temporary casing or augers are withdrawn. Finally, the protective casing can be installed as detailed in Section 5.2.4.

In stable formations where borehole collapse does not occur, the well can be installed as discussed above, and the use of a temporary casing is not needed. However, centralizers may have to be installed, one above and one below the screen, to assure enough annular space for sand pack placement.

5.3.2 Confining Layer Monitoring Wells

When drilling and installing a well in a confined aquifer, proper well installation techniques must be applied to avoid cross contamination between the unconfined and confined aquifer. Under most conditions, this can be accomplished by installing double-cased wells. This is accomplished by drilling a large-diameter boring through the upper aquifer, 1 to 3 feet into the underlying confining layer, and setting and pressure grouting or tremie grouting the outer casing into the confining layer. The grout material must fill the space between the native material and the outer casing. A smaller diameter boring is then continued through the confining layer for installation of the monitoring well as detailed for overburden monitoring wells (with the exception of not using a temporary casing during installation). Sufficient time (determined by the rig geologist), must be allowed for setting of the grout prior to drilling through the confined layer.

5.3.3 Bedrock Monitoring Wells

When installing bedrock monitoring wells, a large diameter boring is drilled through the overburden and approximately 5 feet into the bedrock. A casing (typically steel) is installed and either pressure grouted or tremie grouted in place. After the grout has cured, a smaller diameter boring is continued through the bedrock to the desired depth. If the boring does not collapse, the well can be left open, and a screen is not necessary. If the boring collapses, then a screen is required and can be installed as detailed for overburden monitoring wells. However, if a screen is to be used, then the casing which is installed through the overburden and into the bedrock does not require grouting and can be installed temporary until final well installation is completed.

5.3.4 Drive Points

Drive points can be installed with either a sledge hammer, drop hammer, or a mechanical vibrator. The screen is threaded and tightened onto the riser pipe with pipe wrenches. The drive point is simply pounded into the subsurface to the desired depth. If a heavy drop hammer is used, then a tripod and pulley setup is required to lift the hammer. Drive points typically cannot be driven to depths exceeding 10 feet.

5.3.5 Innovative Monitoring Well Installation Techniques

Certain innovative sampling devices have proven advantageous. These devices are essentially screened samplers installed in a borehole with only one or two small-diameter tubes extending to the surface.

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Manufacturers of these types of samplers claim that four samplers can be installed in a 3-inch-diameter borehole. This reduces drilling costs, decreases the volume of stagnant water, and provides a sampling system that minimizes cross-contamination from sampling equipment. These samplers also perform well when the water table is within 25 feet of the surface (the typical range of suction pumps). Two manufacturers of these samplers are Timco Manufacturing Company, Inc., of Prairie du Sac, Wisconsin, and BARCAD Systems, Inc., of Concord, Massachusetts. Each manufacturer offers various construction materials.

Two additional types of multilevel sampling systems have been developed. Both employ individual screened openings through a small-diameter casing. One of these systems (marketed by Westbay Instruments Ltd. of Vancouver, British Columbia, Canada) uses a screened port and a sampling probe to obtain samples and head measurements or perform permeability tests. This system allows sampling ports at intervals as close as 5 feet, if desired, in boreholes from 3 to 4.8 inches in diameter.

The second system, developed at the University of Waterloo at Waterloo, Ontario, Canada, requires field assembly of the individual sampling ports and tubes that actuate a simple piston pump and force the samples to the surface. Where the depth to ground water is less than 25 feet, the piston pumps are not required. The assembly is made of easily obtained materials; however, the cost of labor to assemble these monitoring systems may not be cost-effective.

5.4 Well Development Methods

The purpose of well development is to stabilize and increase the permeability of the gravel pack around the well screen, and to restore the permeability of the formation which may have been reduced by drilling operations. Wells are typically developed until all fine material and drilling water is removed from the well. Sequential measurements of pH, conductivity and temperature taken during development may yield information (stabilized values) that sufficient development is reached. The selection of the well development method shall be made by the rig geologist and is based on the drilling methods, well construction and installation details, and the characteristics of the formation that the well is screened in. The primary methods of well development are summarized below. A more detailed discussion may be found in Driscoll (1986).

5.4.1 Overpumping and Backwashing

Wells may be developed by alternatively drawing the water level down at a high rate (by pumping or bailing) and then reversing the flow direction (backwashing) so that water is passing from the well into the formation. This back and forth movement of water through the well screen and gravel pack serves to remove fines from the formation immediately adjacent to the well, while preventing bridging (wedging) of sand grains. Backwashing can be accomplished by several methods, including pouring water into the well and then bailing, starting and stopping a pump intermittently to change water levels, or forcing water into the well under pressure through a water-tight fitting ("rawhiding"). Care should be taken when backwashing not to apply too much pressure, which could damage or destroy the well screen.

5.4.2 Surging with a Surge Plunger

A surge plunger (also called a surge block) is approximately the same diameter as the well casing and is used to agitate the water, causing it to move in and out of the screens. This movement of water pulls fine materials into the well, where they may be removed by any of several methods, and prevents bridging of sand particles in the gravel pack. There are two basic types of surge plungers; solid and valved surge plungers. In formations with low yields, a valved surge plunger may be preferred, as solid

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plungers tend to force water out of the well at a greater rate than it will flow back in. Valved plungers are designed to produce a greater inflow than outflow of water during surging.

5.4.3 Compressed Air

Compressed air can be used to develop a well by either of two methods: backwashing or surging. Backwashing is done by forcing water out through the screens, using increasing air pressure inside a sealed well, then releasing the pressurized air to allow the water to flow back into the well. Care should be taken when using this method so that the water level does not drop below the top of the screen, thus reducing well yield. Surging, or the "open well" method, consists of alternately releasing large volumes of air suddenly into an open well below the water level to produce a strong surge by virtue of the resistance of water head, friction, and inertia. Pumping of the well is subsequently done using the air lift method.

5.4.4 High Velocity Jetting

In the high velocity jetting method, water is forced at high velocities from a plunger-type device and through the well screen to loosen fine particles from the sand pack and surrounding formation. The jetting tool is slowly rotated and raised and lowered along the length of the well screen to develop the entire screened area. Jetting using a hose lowered into the well may also be effective. The fines washed into the screen during this process can then be bailed or pumped from the well.

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7.0 RECORDS

A critical part of monitoring well installation is recording of significant details and events in the site logbook or field notebook. The geologist must record the exact depths of significant hydrogeological features screen placement, gravel pack placement, and bentonite placement.

A Monitoring Well Sheet (see Attachments to SOP SA-6.3) shall be completed thus ensuring the uniform recording of data for each installation and rapid identification of missing information. Well depth, length, materials of construction, length and openings of screen, length and type of riser, and depth and type of all backfill materials shall be recorded. Additional information shall include location, installation date, problems encountered, water levels before and after well installation, cross-reference to the geologic boring log, and methods used during the installation and development process. Documentation is very important to prevent problems involving questionable sample validity. Somewhat different information

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will need to be recorded. depending on whether the well is completed in overburden, in a confined layer, in bedrock with a cased well, or as an open hole in bedrock.

The quantities of sand, bentonite, and grout placed in the well are also important. The geologist shall calculate the annular space volume and have a general idea of the quantity of material needed to fill the annular space. Volumes of backfill significantly higher than the calculated volume may indicate a problem such as a large cavity, while a smaller backfill volume may indicate a cave-in. Any problems with rig operation or down-time shall be recorded and may affect the driller's final fee.

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ATTACHMENT A

RELATIVE COMPATIBILITY OF RIGID WELL CASING MATERIAL (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material						
	PVC 1	Galvanized Steel	Carbon Steel	Lo-carbon Steel	Stainless Steel 304	Stainless Steel 316	Teflon*
Buffered Weak Acid	100	56	51	59	97	100	100
Weak Acid	98	59	43	47	96	100	100
Mineral Acid/ High Solids Content	100	48	57	60	80	82	100
Aqueous/Organic Mixtures	64	69	73	73	98	100	100
Percent Overall Rating	91	58	56	59	93	96	100

Preliminary Ranking of Rigid Materials:

- | | | | |
|----|---------------------|---|------------------|
| 1 | Teflon® | 5 | Lo-Carbon Steel |
| 2 | Stainless Steel 316 | 6 | Galvanized Steel |
| 3. | Stainless Steel 304 | 7 | Carbon Steel |
| 4 | PVC 1 | | |

* Trademark of DuPont

RELATIVE COMPATIBILITY OF SEMI-RIGID OR ELASTOMERIC MATERIALS (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material								
	PVC Flexible	PP	PE Conv.	PE Linear	PMM	Viton®*	Silicone	Neoprene	Teflon®*
Buffered Weak Acid	97	97	100	97	90	92	87	85	100
Weak Acid	92	90	94	96	78	78	75	75	100
Mineral Acid/ High Solids Content	100	100	100	100	95	100	78	82	100
Aqueous/Organic Mixtures	62	71	40	60	49	78	49	44	100
Percent Overall Rating	88	90	84	88	78	87	72	72	100

Preliminary Ranking of Semi-Rigid or Elastomeric Materials:

- | | | | |
|----|------------------------|---|------------------------|
| 1 | Teflon® | 5 | PE Conventional |
| 2 | Polypropylene (PP) | 6 | Plexiglas/Lucite (PMM) |
| 3. | PVC Flexible/PE Linear | 7 | Silicone/Neoprene |
| 4 | Viton® | | |

* Trademark of DuPont

Source: Barcelona et al., 1983

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ATTACHMENT B

COMPARISON OF STAINLESS STEEL AND PVC FOR MONITORING WELL CONSTRUCTION

Characteristic	Stainless Steel	PVC
Strength	Use in deep wells to prevent compression and closing of screen/riser.	Use when shear and compressive strength are not critical.
Weight	Relatively heavier.	Light-weight; floats in water.
Cost	Relatively expensive.	Relatively inexpensive.
Corrosivity	Deteriorates more rapidly in corrosive water.	Non-corrosive -- may deteriorate in presence of ketones, aromatics, alkyl sulfides, or some chlorinated hydrocarbons.
Ease of Use	Difficult to adjust size or length in the field.	Easy to handle and work with in the field.
Preparation for Use	Should be steam cleaned organics will be subsequently sampled.	Never use glue fittings -- pipes should be threaded or pressure fitted. Should be steam cleaned when used for monitoring wells.
Interaction with Contaminants*	May sorb organic or inorganic substances when oxidized.	May sorb or release organic substances.

* See also Attachment A.



BROWN & ROOT ENVIRONMENTAL

STANDARD OPERATING PROCEDURES

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Applicability
B&R Environmental, NE

Prepared
Earth Sciences Department

Subject

GROUNDWATER SAMPLE ACQUISITION AND ONSITE WATER
QUALITY TESTING

Approved
D. Senovich

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information regarding the sampling of groundwater wells.

2.0 SCOPE

This procedure provides information on proper sampling equipment, onsite water quality testing, and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described shall be followed whenever applicable, noting that site-specific conditions or project-specific plans may require modifications to methodology.

3.0 GLOSSARY

Conductance - The conductance of a conductor 1 centimeter long and 1 square centimeter in cross-sectional area. For groundwater measurements, a volume of water contained in a 1 cm x 1 cm sample container (the water acts as the conductor). Conductivity and specific conductance are used synonymously.

Electrolytic Cell - An electrochemical cell in which electrical energy is supplied from an external source. This cell functions in much the same way as a galvanic cell, only the current flows in the opposite direction due to the external source of applied voltage. Electrolytic cells are used in dissolved oxygen measurement.

Galvanic Cell - A electrochemical cell in which chemical energy is spontaneously converted to electrical energy. The electrical energy produced is supplied to an external circuit. Galvanic cells are used in dissolved oxygen measurement.

Ohm - Standard unit of electrical resistance (R). Used in specific conductance measurement. A siemen (or umho) is the standard unit of electrical conductance, the inverse of the ohm.

Oxidation-Reduction Potential (ORP) - A measure of the activity ratio of oxidizing and reducing species as determined by the electromotive force developed by a noble metal electrode, immersed in water, as referenced against a standard hydrogen electrode.

pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration.

pH Paper - Indicator paper that turns different colors depending on the pH of the solution to which it is exposed. Comparison with color standards supplied by the manufacturer will then give an indication of the solution's pH.

Resistance - A measure of the solution's ability to oppose the passage of electrical current. For metals and solutions, resistance is defined by Ohm's Law, $E = IR$, where E is the potential difference, I is the current, and R is the resistance. Used in measurement of specific conductance.

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4.0 RESPONSIBILITIES

Project Hydrogeologist - Responsible for selecting and detailing the specific groundwater sampling techniques, onsite water quality testing (type, frequency, and location), and equipment to be used, and providing detailed input in this regard to the project plan documents. The project hydrogeologist is also responsible for properly briefing and overseeing the performance of the site sampling personnel.

Project Geologist - is primarily responsible for the proper acquisition of the groundwater samples. He/she is also responsible for the actual analyses of onsite water quality samples, as well as instrument calibration, care, and maintenance. When appropriate, such responsibilities may be performed by other qualified personnel (e.g., field technicians).

5.0 PROCEDURES

5.1 General

To be useful and accurate, a groundwater sample must be representative of the particular zone of the water being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of analysis in order to keep any changes in water quality parameters to a minimum.

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach shall be followed prior to sample acquisition:

1. All monitoring wells shall be purged prior to obtaining a sample. Evacuation of three to five volumes is recommended prior to sampling. In a high-yielding groundwater formation and where there is no stagnant water in the well above the screened section, extensive evacuation prior to sample withdrawal is not as critical.
2. For wells that can be purged dry, the well shall be evacuated and allowed to recover prior to sample acquisition. If the recovery rate is fairly rapid, evacuation of more than one volume of water is required.
3. For high-yielding monitoring wells which cannot be evacuated to dryness, there is no absolute safeguard against contaminating the sample with stagnant water. One of the following techniques shall be used to minimize this possibility:
 - A submersible pump or the intake line of a surface pump or bailer shall be placed just below the water surface when removing the stagnant water and lowered as the water level drops. Three to five volumes of water shall be removed to provide reasonable assurance that all stagnant water has been evacuated. Once this is accomplished, a bailer or other approved device may be used to collect the sample for analysis.

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- The intake line of the sampling pump (or the submersible pump itself) shall be placed near the bottom of the screened section, and approximately one casing volume of water shall be pumped from the well at a low purge rate, equal to the well's recovery rate (low flow sampling).

Stratification of contaminants may exist in the aquifer. Concentration gradients as a result of mixing and dispersion processes, layers of variable permeability, and the presence of separate-phase product (i.e., floating hydrocarbons) may cause stratification. Excessive pumping or improper sampling methods can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column as it naturally occurs at that point, thus the result is the collection of a non-representative sample.

5.2 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with the guidelines expressed in SOP SA-6.1.

The following equipment shall be on hand when sampling ground water wells (reference SOPs SA-6.1 and SA-7.1):

- Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, appropriate sampling containers and filler, ice, labels and chain-of-custody documents.
- Field tools and instrumentation - Thermometer, pH paper/meter, camera and film (if appropriate), appropriate keys (for locked wells), engineer's rule, water level indicator, specific conductivity meter, and turbidity meter (as applicable).
- Pumps
 - Shallow-well pumps: Centrifugal, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing) where applicable.
 - Deep-well pumps: Submersible pump and electrical power-generating unit, or air-lift apparatus where applicable.
- Other sampling equipment - Bailers and inert line with tripod-pulley assembly (if necessary). Bailers or submersible centrifugal pumps shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.
- Pails - Plastic, graduated.
- Decontamination solutions - Deionized water, laboratory detergents, 10% nitric acid solution (as required), and analytical-grade solvents (e.g., methanol, acetone, hexane), as required.

Ideally, sample withdrawal equipment shall be completely inert, economical, easily cleaned, cleaned prior to use, reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well flushing and sample collection.

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5.3 Calculations of Well Volume

To insure that the proper volume of water has been removed from the well prior to sampling it is first necessary to know the volume of standing water in the well pipe. This volume can be easily calculated by the following method. Calculations shall be entered in the site logbook or field notebook or on a sample log sheet form (see SOP SA-6.3):

- Obtain all available information on well construction (location, casing, screens, etc.).
- Determine well or casing diameter.
- Measure and record static water level (depth below ground level or top of casing reference point).
- Determine depth of well by sounding using a clean, decontaminated, weighted tape measure.
- Calculate number of linear feet of static water (total depth or length of well pipe minus the depth to static water level).

- Calculate one static well volume in gallons $V = (0.163)(T)(r^2)$

where: V = Static volume of well in gallons.
 T = Thickness of water table in the well measured in feet (i.e., linear feet of static water).
 r = Inside radius of well casing in inches.
0.163 = A constant conversion factor which compensates for the conversion of the casing radius from inches to feet, the conversion of cubic feet to gallons, and pi.

- Per evacuation volumes discussed above, determine the minimum amount to be evacuated before sampling.

5.4 Evacuation of Static Water (Purging)

5.4.1 General

The amount of purging a well shall receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer. Alternately the well can be pumped until the parameters such as temperature, electrical conductance, pH, and turbidity (as applicable), have stabilized. Onsite measurements of these parameters shall be recorded in the site logbook, field notebook, or on standardized data sheets.

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5.4.2 Evacuation Devices

The following discussion is limited to those devices commonly used at hazardous waste sites. Attachment A provides guidance on the proper evacuation device to use for given sampling situations. Note that all of these techniques involve equipment which is portable and readily available.

Bailers

Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Bailers are inexpensive, and can be dedicated and hung in a well to reduce the chances of cross-contamination.
- There is minimal outgassing of volatile organics while the sample is in the bailer.
- Bailers are relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- It is time consuming to remove stagnant water using a bailer.
- Transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.

Suction Pumps

There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 20 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps can cause significant loss of dissolved gases and volatile organics.

Air-Lift Samplers

This group of pump samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Air (or gas)-lift samplers are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation, or loss of volatile organics.

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Submersible Pumps

Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed gas or electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for 2-inch-diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- They may have low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components can be difficult and time-consuming.

5.5 Onsite Water Quality Testing

This section describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance
- Temperature
- Dissolved Oxygen (DO) Concentration
- Oxidation Reduction Potential
- Certain Dissolved Constituents Using Specific Ion Elements
- Turbidity

This section is applicable for use in an onsite groundwater quality monitoring program to be conducted at a hazardous or nonhazardous site. The procedures and equipment described are applicable to groundwater samples and are not, in general, subject to solution interferences from color, turbidity, and colloidal material or suspended matter.

This section provides general information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

5.5.1 Measurement of pH

5.5.1.1 General

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment such as acid-base neutralization, water softening, and corrosion control is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

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Two methods are given for pH measurement: the pH meter and pH indicator paper. The indicator paper is used when only a rough estimate of the pH is required, and the pH meter when a more accurate measurement is needed. The response of a pH meter can be affected to a slight degree by high levels of colloidal or suspended solids, but the effect is usually small and generally of little significance. Consequently, specific methods to overcome this interference are not described. The response of pH paper is unaffected by solution interferences from color, turbidity, colloidal or suspended materials unless extremely high levels capable of coating or masking the paper are encountered. In such cases, use of a pH meter is recommended.

5.5.1.2 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or basicity of the solution created by the addition of the water sample reacting with the indicator compound on the paper. Various types of pH papers are available, including litmus (for general acidity or basicity determination) and specific pH range hydron paper.

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on establishment of a potential difference across a glass or other type of membrane in response to (in this instance, hydrogen) ion concentration across that membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to the ion concentration is generated and measured.

5.5.1.3 Equipment

The following equipment is needed for taking pH measurements:

- Stand-alone 150 portable pH meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Combination electrode with polymer body to fit the above meter (alternately a pH electrode and a reference electrode can be used if the pH meter is equipped with suitable electrode inputs).
- Buffer solutions, as specified by the manufacturer.
- pH indicator paper, to cover the pH range 2 through 12.
- Manufacturer's operation manual.

5.5.1.4 Measurement Techniques for Field Determination of pH

pH Meter

The following procedure is used for measuring pH with a pH meter (meter standardization is according to manufacturer's instructions):

- Inspect the instrument and batteries prior to initiation of the field effort.
- Check the integrity of the buffer solutions used for field calibration. Buffer solutions need to be changed often as a result of degradation upon exposure to the atmosphere.

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- Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage. This is not applicable for all electrodes as some must be stored dry.
- If applicable, make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).
- Calibrate on a daily use basis following manufacturer's instructions. Record calibration data on an equipment calibration log sheet.
- Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a physical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.
- Read and record the pH of the solution. pH shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature.
- Rinse the electrode(s) with deionized water.
- Store the electrode(s) in an appropriate manner when not in use.

Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted.

pH Paper

Use of pH paper is very simple and requires no sample preparation, standardization, etc. pH paper is available in several ranges, including wide-range (indicating approximately pH 1 to 12), mid-range (approximately pH 0 to 6, 6 to 9, 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown the investigation shall start with wide-range paper and proceed with successively narrower range paper until the sample pH is adequately determined.

5.5.2 Measurement of Specific Conductance

5.5.2.1 General

Conductance provides a measure of dissolved ionic species in water and can be used to identify the direction and extent of migration of contaminants in groundwater or surface water. It can also be used as a measure of subsurface biodegradation or to indicate alternate sources of groundwater contamination.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

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It is important to obtain a specific conductance measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

5.5.2.2 Principles of Equipment Operation

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions migrate toward the negative electrode, while the negatively charged ions migrate toward the positive electrode. Most inorganic acids, bases and salts (such as hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not disassociate in aqueous solution, conduct a current very poorly, if at all.

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell may also be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

5.5.2.3 Equipment

The following equipment is needed for taking specific conductance (SC) measurements:

- Stand alone portable conductivity meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

A variety of conductivity meters are available which may also be used to monitor salinity and temperatures. Probe types and cable lengths vary, so equipment must be obtained to meet the specific requirement of the sampling program.

5.5.2.4 Measurement Techniques for Specific Conductance

The steps involved in taking specific conductance measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate instrument before going into the field.
- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet. Potassium chloride solutions with a SC closest to the values expected in the field shall be used for calibration. Attachment B provides guidance in this regard.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.

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- Immerse the electrode in the sample and measure the conductivity. Adjust the temperature setting to the sample temperature (if applicable).
- Read and record the results in a field logbook or sample log sheet.
- Rinse the electrode with deionized water.

If the specific conductance measurements become erratic, recalibrate the instrument and see the manufacturer's instructions for details.

5.5.3 Measurement of Temperature

5.5.3.1 General

In combination with other parameters, temperature can be a useful indicator of the likelihood of biological action in a water sample. It can also be used to trace the flow direction of contaminated groundwater. Temperature measurements shall be taken in-situ, or as quickly as possible in the field. Collected water samples may rapidly equilibrate with the temperature of their surroundings.

5.5.3.2 Equipment

Temperature measurements may be taken with alcohol-toluene, mercury filled or dial-type thermometers. In addition, various meters such as specific conductance or dissolved oxygen meters, which have temperature measurement capabilities, may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature at great depths can be performed.

5.5.3.3 Measurement Techniques for Water Temperature

If a thermometer is used to determine the temperature for a water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of cross-contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.
- Record values in a field logbook or sample log sheet.

If a temperature meter or probe is used, the instrument shall be calibrated according to manufacturer's recommendations.

5.5.4 Measurement of Dissolved Oxygen Concentration

5.5.4.1 General

Dissolved oxygen (DO) levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. Conversely, the growth of many aquatic organisms as well as the rate of corrosivity, are dependent on the dissolved oxygen concentration. Thus, analysis for dissolved oxygen is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ, since concentration may show a large change in a short time if the sample is not adequately preserved.

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The monitoring method discussed herein is limited to the use of dissolved oxygen meters only. Chemical methods of analysis (i.e., Winkler methods) are available, but require more equipment and greater sample manipulation. Furthermore, DO meters, using a membrane electrode, are suitable for highly polluted waters, because the probe is completely submersible, and is not susceptible to interference caused by color, turbidity, colloidal material or suspended matter.

5.5.4.2 Principles of Equipment Operation

Dissolved oxygen probes are normally electrochemical cells that have two solid metal electrodes of different nobility immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of highest nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH) occurs at the cathode surface. An electrical current is developed that is directly proportional to the rate of arrival of oxygen molecules at the cathode.

Since the current produced in the probe is directly proportional to the rate of arrival of oxygen at the cathode, it is important that a fresh supply of sample always be in contact with the membrane. Otherwise, the oxygen in the aqueous layer along the membrane is quickly depleted and false low readings are obtained. It is therefore necessary to stir the sample (or the probe) constantly to maintain fresh solution near the membrane interface. Stirring, however, shall not be so vigorous that additional oxygen is introduced through the air-water interface at the sample surface. To avoid this possibility, some probes are equipped with stirrers to agitate the solution near the probe, while leaving the surface of the solution undisturbed.

Dissolved oxygen probes are relatively unaffected by interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide, which are not easily depolarized from the indicating electrode. If a gaseous interference is suspected, it shall be noted in the field log book and checked if possible. Temperature variations can also cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation is normally provided by the manufacturer.

5.5.4.3 Equipment

The following equipment is needed to measure dissolved oxygen concentration:

- Stand alone portable dissolved oxygen meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Sufficient cable to allow the probe to contact the sample.
- Manufacturer's operation manual.

5.5.4.4 Measurement Techniques for Dissolved Oxygen Determination

Probes differ as to specifics of use. Follow the manufacturer's instructions to obtain an accurate reading. The following general steps shall be used to measure the dissolved oxygen concentration:

- The equipment shall be calibrated and have its batteries checked in the warehouse before going to the field.

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- The probe shall be conditioned in a water sample for as long a period as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.
- The instrument shall be calibrated in the field according to manufacturer's recommendations or in a freshly air-saturated water sample of known temperature. Dissolved oxygen values for air-saturated water can be determined by consulting a table listing oxygen solubilities as a function of temperature and salinity (see Attachment C).
- Record all pertinent information on an equipment calibration sheet.
- Rinse the probe with deionized water.
- Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane by stirring the sample. Probes without stirrers placed in wells can be moved up and down.
- Record the dissolved oxygen content and temperature of the sample in a field logbook or sample log sheet.
- Rinse the probe with deionized water.
- Recalibrate the probe when the membrane is replaced, or as needed. Follow the manufacturer's instructions.

Note that in-situ placement of the probe is preferable, since sample handling is not involved. This however, may not always be practical. Be sure to record whether the liquid was analyzed in-situ, or if a sample was taken.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen solubilization and positive test interferences.

5.5.5 Measurement of Oxidation-Reduction Potential

5.5.5.1 General

The oxidation-reduction potential (ORP) provides a measure of the tendency of organic or inorganic compounds to exist in an oxidized state. The ORP parameter therefore provides evidence of the likelihood of anaerobic degradation of biodegradable organics or the ratio of activities of oxidized to reduced species in the sample.

5.5.5.2 Principles of Equipment Operation

When an inert metal electrode, such as platinum, is immersed in a solution, a potential is developed at that electrode depending on the ions present in the solution. If a reference electrode is placed in the same solution, an ORP electrode pair is established. This electrode pair allows the potential difference between the two electrodes to be measured and is dependent on the concentration of the ions in solution. By this measurement, the ability to oxidize or reduce species in solution may be determined. Supplemental measurements, such as dissolved oxygen, may be correlated with ORP to provide a knowledge of the quality of the solution, water, or wastewater.

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5.5.5.3 Equipment

The following equipment is needed for measuring the oxidation-reduction potential of a solution:

- Portable pH meter or equivalent, with a millivolt scale.
- Platinum electrode to fit above pH meter.
- Reference electrode such as a calomel, silver-silver chloride, or equivalent.
- Reference solution as specified by the manufacturer.
- Manufacturer's operation manual.

5.5.5.4 Measurement Techniques for Oxidation-Reduction Potential

The following procedure is used for measuring oxidation-reduction potential:

- The equipment shall be calibrated and have its batteries checked before going to the field.
- Check that the platinum probe is clean and that the platinum bond or tip is unoxidized. If dirty, polish with emery paper or, if necessary, clean the electrode using aqua regia, nitric acid, or chromic acid, in accordance with manufacturer's instructions.
- Thoroughly rinse the electrode with deionized water.
- Verify the sensitivity of the electrodes by noting the change in millivolt reading when the pH of the test solution is altered. The ORP will increase when the pH of the test solution decreases and the ORP will decrease if the test solution pH is increased. Place the sample in a clean container and agitate the sample. Insert the electrodes and note the ORP drops sharply when the caustic is added (i.e., pH is raised) thus indicating the electrodes are sensitive and operating properly. If the ORP increases sharply when the caustic is added, the polarity is reversed and must be corrected in accordance with the manufacturer's instructions. If the ORP does not respond as above when the caustic is added, the electrodes shall be cleaned and the above procedure repeated.
- After the assembly has been checked for sensitivity, wash the electrodes with three changes of water or by means of a flowing stream of deionized water from a wash bottle. Place the sample in a clean container and insert the electrodes. Set temperature compensator throughout the measurement period. Read the millivolt potential of the solution, allowing sufficient time for the system to stabilize and reach temperature equilibrium. Measure successive portions of the sample until readings on two successive portions differ by no more than 10 mV. A system that is very slow to stabilize properly will not yield a meaningful ORP. Record all results in a field logbook or sample logsheet, including ORP (to nearest 10 mV), sample temperature and pH at the time of measurement.

5.5.6 Measurement of Turbidity

5.5.6.1 General

Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and microscopic organisms, including plankton. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample.

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It is important to obtain a turbidity reading immediately after taking a sample, since irreversible changes in turbidity may occur if the sample is stored too long.

5.5.6.2 Principles of Equipment Operation

Turbidity is measured by the Nephelometric Method. This method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the scattered light intensity, the higher the turbidity.

Formazin polymer is used as the reference turbidity standard suspension because of its ease of preparation combined with a higher reproducibility of its light-scattering properties than clay or turbid natural water. The turbidity of a specified concentration of formazin suspension is defined as 40 nephelometric units. This same suspension has an approximate turbidity of 40 Jackson units when measured on the candle turbidimeter. Therefore, nephelometric turbidity units (NTU) based on the formazin preparation will approximate units derived from the candle turbidimeter but will not be identical to them.

5.5.6.3 Equipment

The following equipment is needed for turbidity measurement:

- Stand alone portable turbidity meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

5.5.6.4 Measurements Techniques for Specific Conductance

The steps involved in taking turbidity measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate instrument before going into the field.
- Check the expiration date (etc.) of the solutions used for field calibration.
- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.
- Immerse the probe in the sample and measure the turbidity. The reading must be taken immediately as suspended solids will settle over time resulting in a lower, inaccurate turbidity reading.

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- Read and record the results in a field logbook or sample log sheet. Include a physical description of the sample, including color, qualitative estimate of turbidity, etc.
- Rinse the electrode with deionized water.

5.6 Sampling

5.6.1 Sampling Plan

The sampling approach consisting of the following, shall be developed as part of the project plan documents which are approved prior to beginning work in the field:

- Background and objectives of sampling.
- Brief description of area and waste characterization.
- Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
- Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these shall be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.
- Sample preservation requirements.
- Work schedule.
- List of team members.
- List of observers and contacts.
- Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

5.6.2 Sampling Methods

The collection of a groundwater sample consists of the following steps:

1. The site Health & Safety Officer (or designee) will first open the well cap and use volatile organic detection equipment (PID or FID) on the escaping gases at the well head to determine the need for respiratory protection.
2. When proper respiratory protection has been donned, sound the well for total depth and water level (using clean equipment) and record these data on a groundwater sampling log sheet (see SOP SA-6.3); then calculate the fluid volume in the well pipe (as previously described in this SOP).
3. Calculate well volume to be removed as stated in Section 5.3.

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4. Select the appropriate purging equipment (see Attachment A). If an electric submersible pump with packer is chosen, go to Step 10.
5. Lower the purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (as applicable). Lower the purging device, as required, to maintain submergence.
6. Measure the rate of discharge frequently. A graduated bucket and stopwatch are most commonly used; other techniques include use of pipe trajectory methods, weir boxes or flow meters.
7. Observe the peristaltic pump intake for degassing "bubbles." If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. Never collect volatile organics samples using a vacuum pump.
8. Purge a minimum of three to five casing volumes before sampling. In low-permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Purged water shall be collected in a designated container and disposed in an acceptable manner.
9. If sampling using a pump, lower the pump intake to midscreen (or the middle of the open section in uncased wells) and collect the sample. If sampling with a bailer, lower the bailer to the sampling level before filling.
10. (For pump and packer assembly only). Lower the assembly into the well so that the packer is positioned just above the screen or open section. Inflate the packer. Purge a volume equal to at least twice the screened interval (or unscreened open section volume below the packer) before sampling. Packers shall always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
11. In the event that recovery time of the well is very slow (e.g., 24 hours or greater), sample collection can be delayed until the following day. If the well has been purged early in the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record this occurrence in the site logbook.
12. Fill sample containers (preserve and label as described in SOP SA-6.1).
13. Replace the well cap and lock as appropriate. Make sure the well is readily identifiable as the source of the samples.
14. Process sample containers as described in SOP SA-6.1.
15. Decontaminate equipment as described in SOP SA-7.1.

5.7 Low Flow Purging and Sampling

5.7.1 Scope & Application

Low flow purging and sampling techniques are sometimes required for groundwater sampling activities. The purpose of low flow purging and sampling is to collect groundwater samples that contain

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"representative" amounts of mobile organic and inorganic constituents in the vicinity of the selected open well interval, at near natural flow conditions. The minimum stress procedure emphasizes negligible water level drawdown and low pumping rates in order to collect samples with minimal alterations in water chemistry. This procedure is designed primarily to be used in wells with a casing diameter of 2 inches or more and a saturated screen, or open interval, length of ten feet or less. Samples obtained are suitable for analyses of common types of groundwater contaminants (volatile and semi-volatile organic compounds, pesticides, PCBs, metals and other inorganic ions [cyanide, chloride, sulfate, etc.]). This procedure is not designed to collect non-aqueous phase liquids samples from wells containing light or dense non-aqueous phase liquids (LNAPLs or DNAPLs), using the low flow pumps.

The procedure is flexible for various well construction types and groundwater yields. The goal of the procedure is to obtain a turbidity level of less than 5 NTU and to achieve a water level drawdown of less than 0.3 feet during purging and sampling. If these goals cannot be achieved, sample collection can take place provided the remaining criteria in this procedure are met.

5.7.2 Equipment

The following equipment is required (as applicable) for low flow purging and sampling:

- Adjustable rate, submersible pump (e.g., centrifugal or bladder pump constructed of stainless steel or Teflon). Peristaltic pumps may be used only for inorganic sample collection.
- Disposable clear plastic bottom filling bailers may be used to check for and obtain samples of LNAPLs or DNAPLs.
- Tubing - Teflon, Teflon lined polyethylene, polyethylene, PVC, tygon steel tubing can be used to collect samples for analysis, depending on the analyses to be performed and regulatory requirements.
- Water level measuring device, 0.01 foot accuracy, (electronic devices are preferred for tracking water level drawdown during all pumping operations).
- Flow measurement supplies.
- Interface probe, if needed.
- Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at a safe distance from the well so that the exhaust fumes do not contaminate the samples.
- Indicator parameter monitoring instruments - pH, turbidity, specific conductance, and temperature. Use of a flow-through cell is recommended. Optional Indicators - eH and dissolved oxygen, flow-through cell is required. Standards to perform field calibration of instruments.
- Decontamination supplies.
- Logbook(s), and other forms (e.g., well purging forms).
- Sample Bottles.

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- Sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Well construction data, location map, field data from last sampling event.
- Field Sampling Plan.
- PID or FID instrument for measuring VOCs (volatile organic compounds).

5.7.3 Purging and Sampling Procedure

Use a submersible pump to purge and sample monitoring wells which have a 2.0 inch or greater well casing diameter.

Measure and record the water level immediately prior to placing the pump in the well.

Lower pump, safety cable, tubing and electrical lines slowly into the well so that the pump intake is located at the center of the saturated screen length of the well. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of sediment that may be present in the bottom of the well. Collection of turbid free water samples may be difficult if there is three feet or less of standing water in the well.

When starting the pump, slowly increase the pump speed until a discharge occurs. Check water level. Adjust pump speed to maintain little or no water level drawdown. The target drawdown should be less than 0.3 feet and it should stabilize. If the target of less than 0.3 feet cannot be achieved or maintained, the sampling is acceptable if remaining criteria in the procedure are met. Subsequent sampling rounds will probably have intake settings and extraction rates that are comparable to those used in the initial sampling rounds.

Monitor water level and pumping rate every three to five minutes (or as appropriate) during purging. Record pumping rate adjustments and depths to water. Pumping rates should, as needed, be reduced to the minimum capabilities of the pump (e.g., 0.1-0.2 l/min) to ensure stabilization of indicator parameters. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During initial pump start-up, drawdown may exceed the 0.3 feet target and then recover as pump flow adjustments are made (minimum purge volume calculations should utilize stabilized drawdown values, not the initial drawdown). If the recharge rate of the well is less than minimum capability of the pump do not allow the water level to fall to the intake level (if the static water level is above the screen, avoid lowering the water level into the screen). Shut off the pump if either of the above is about to occur and allow the water level to recover. Repeat the process until field indicator parameters stabilize and the minimum purge volume is removed. The minimum purge volume with negligible drawdown (0.3 feet or less) is two saturated screen length volumes. In situations where the drawdown is greater than 0.3 feet and has stabilized, the minimum purge volume is two times the saturated screen volume plus the stabilized drawdown volume. After the minimum purge volume is attained (and field parameters have stabilized) begin sampling. For low yields wells, commence sampling as soon as the well has recovered sufficiently to collect the appropriate volume for all anticipated samples.

During well purging, monitor field indicator parameters (turbidity, temperature, specific conductance, pH, etc.) every three to five minutes (or as appropriate). Purging is complete and sampling may begin when

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all field indicator parameters have stabilized (variations in values are within ten percent of each other, pH +/- 0.2 units, for three consecutive readings taken at three to five minute intervals). If the parameters have stabilized, but turbidity remains above 5 NTU goal, decrease pump flow rate, and continue measurement of parameters every three to five minutes. If pumping rate cannot be decreased any further and stabilized turbidity values remain above 5 NTU goal record this information. Measurements of field parameters should be obtained (as per Section 5.5) and recorded.

VOC samples are preferably collected first and directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

If the water column in the pump tubing collapses (water does not completely fill the tubing) before exiting the tubing, use one of the following procedures to collect VOC samples: (1) Collect the non-VOCs samples first, then increase the flow rate incrementally until the water column completely fills the tubing, collect the sample and record the new flow rate; (2) reduce the diameter of the existing tubing until the water column fills the tubing either by adding a connector (Teflon or stainless steel), or clamp which should reduce the flow rate by constricting the end of the tubing; (3) insert a narrow diameter Teflon tube into the pump's tubing so that the end of the tubing is in the water column and the other end of the tubing protrudes beyond the pump's tubing, collect sample from the narrow diameter tubing.

Prepare samples for shipping as per SOP SA-6.1.

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ATTACHMENT A

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Diameter Casing		Bailer	Peristaltic Pump	Vacuum Pump	Air-lift	Diaphragm "Trash" Pump	Submersible Diaphragm Pump	Submersible Electric Pump	Submersible Electric Pump w/Packer
1.25-Inch	Water level < 25 feet		X	X	X	X			
	Water Level > 25 feet				X				
2-Inch	Water level < 25 feet	X	X	X	X	X	X		
	Water Level > 25 feet	X			X		X		
4-Inch	Water level < 25 feet	X	X	X	X	X	X	X	X
	Water Level > 25 feet	X			X		X	X	X
6-Inch	Water level < 25 feet				X	X		X	X
	Water Level > 25 feet				X			X	X
8-Inch	Water level < 25 feet				X	X		X	X
	Water Level > 25 feet				X			X	X

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Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/Length (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
BarCad Systems, Inc.	BarCad Sampler	Dedicated; gas drive (positive displacement)	1.5/16	PE, brass, nylon, aluminum oxide	0-150 with std. tubing	1 liter for each 10-15 feet of submergence	\$220-350	Requires compressed gas; custom sizes and materials available; acts as piezometer.
Cole-Parmer Inst. Co.	Master Flex 7570 Portable Sampling Pump	Portable; peristaltic (suction)	< 1.0/NA	Tygon [®] , silicone Viton [®]	0-30	670 mL/min with 7015-20 pump head	\$500-600	AC/DC; variable speed control available; other models may have different flow rates.
ECO Pump Corp.	SAMPLifier	Portable; venturi	< 1.5 or < 2.0/NA	PP, PE, PVC, SS, Teflon [®] , Tefzel [®]	0-100	0-500 mL/min depending on lift	\$400-700	AC, DC, or gasoline-driven motors available; must be primed.
Geltek Corp.	Bailer 219-4	Portable; grab (positive displacement)	1.66/38	Teflon [®]	No limit	1,075 mL	\$120-135	Other sizes available.
GeoEngineering, Inc.	GEO-MONITOR	Dedicated; gas drive (positive displacement)	1.5/16	PE, PP, PVC, Viton [®]	Probably 0-150	Approximately 1 liter for each 10 feet of submergence	\$185	Acts as piezometer; requires compressed gas.
Industrial and Environmental Analysts, Inc. (IEA)	Aquarius	Portable; bladder (positive displacement)	1.75/43	SS, Teflon [®] , Viton [®]	0-250	0-2,800 mL/min	\$1,500-3,000	Requires compressed gas; other models available; AC, DC, manual operation possible.
IEA	Syringe Sampler	Portable; grab (positive displacement)	1.75/43	SS, Teflon [®]	No limit	850 mL sample volume	\$1,100	Requires vacuum and/or pressure from hand pump.
Instrument Specialties Co. (ISCO)	Model 2600 Well Sampler	Portable; bladder (positive displacement)	1.75/50	PC, silicone, Teflon [®] , PP, PE, Detrin [®] , acetal	0-150	0-7,500 mL/min	\$990	Requires compressed gas (40 psi minimum).
Keck Geophysical Instruments, Inc.	SP-81 Submersible Sampling Pump	Portable; helical rotor (positive displacement)	1.75/25	SS, Teflon [®] , PP, EPDM, Viton [®]	0-160	0-4,500 mL/min	\$3,500	DC operated.
Leonard Mold and Die Works, Inc.	GeoFilter Small Diameter Well Pump (#0500)	Portable; bladder (positive displacement)	1.75/38	SS, Teflon [®] , PC, Neoprene [®]	0-400	0-3,500 mL/min	\$1,400-1,500	Requires compressed gas (55 psi minimum); pneumatic or AC/DC control module.
Oil Recovery Systems, Inc.	Surface Sampler	Portable; grab (positive displacement)	1.75/12	acrylic, Detrin [®]	No limit	Approximately 250 mL	\$125-160	Other materials and models available; for measuring thickness of "floating" contaminants.
Q.E.D. Environmental Systems, Inc.	Well Wizard [®] Monitoring System (P-100)	Dedicated; bladder (positive displacement)	1.66/36	PVC	0-230	0-2,000 mL/min	\$300-400	Requires compressed gas; piezometric level indicator; other materials available.

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Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/Length (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
Randolph Austin Co.	Model 500 Vari-Flow Pump	Portable; peristaltic (suction)	< 0.5/NA	(Not submersible) Rubber, Tygon®, or Neoprene®	0-30	See comments	\$1,200-1,300	Flow rate dependent on motor and tubing selected; AC operated; other models available.
Robert Bennett Co.	Model 180	Portable; piston (positive displacement)	1.8/22	SS, Teflon®, Delrin®, PP, Viton®, acrylic, PE	0-500	0-1,800 mL/min	\$2,600-2,700	Requires compressed gas; water level indicator and flow meter; custom models available.
Slope Indicator Co. (SINCO)	Model 514124 Pneumatic Water Sampler	Portable; gas drive (positive displacement)	1.9/18	PVC, nylon	0-1,100	250 mL/flushing cycle	\$250-350	Requires compressed gas; SS available; piezometer model available; dedicated model available.
Solinst Canada Ltd.	5W Water Sampler	Portable; grab (positive displacement)	1.9/27	PVC, brass, nylon, Neoprene®	0-330	500 mL	\$1,300-1,800	Requires compressed gas; custom models available.
TIMCO Mfg. Co., Inc.	Std. Bailer	Portable; grab (positive displacement)	1.66/Custom	PVC, PP	No limit	250 mL/ft of bailer	\$20-60	Other sizes, materials, models available; optional bottom-empting device available; no solvents used.
TIMCO	Air or Gas Lift Sampler	Portable; gas drive (positive displacement)	1.66/30	PVC, Tygon®, Teflon®	0-150	350 mL/flushing cycle	\$100-200	Requires compressed gas; other sizes, materials, models available; no solvents used.
Tote Devices Co.	Sampling Pump	Portable; bladder (positive displacement)	1.38/48	SS, silicone, Delrin®, Tygon®	0-125	0-4,000 mL/min	\$800-1,000	Compressed gas required; DC control module; custom built.

Construction Material Abbreviations:

PE Polyethylene
PP Polypropylene
PVC Polyvinyl chloride
SS Stainless steel
PC Polycarbonate
EPDM Ethylene-propylene diene (synthetic rubber)

Other Abbreviations:

NA Not applicable
AC Alternating current
DC Direct current

NOTE: Other manufacturers market pumping devices which could be used for groundwater sampling, though not expressly designed for this purpose. The list is not meant to be all-inclusive and listing does not constitute endorsement for use. Information in the table is from sales literature and/or personal communication.
No skimmer, scavenger-type, or high-capacity pumps are included.

Source: Barcelona et al., 1983.

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ATTACHMENT B

SPECIFIC CONDUCTANCE OF 1 MOLAR KCl AT VARIOUS TEMPERATURES¹

Temperature (°C)	Specific Conductance (umhos/cm)
15	1,147
16	1,173
17	1,199
18	1,225
19	1,251
20	1,278
21	1,305
22	1,332
23	1,359
24	1,368
25	1,413
26	1,441
27	1,468
28	1,496
29	1,524
30	1,552

¹ Data derived from the International Critical
Tables 1-3-8.

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ATTACHMENT C

VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY

Temperature (°C)	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/ 100 mg Chloride
	0	5,000	10,000	15,000	20,000	
0	14.6	13.8	13.0	12.1	11.3	0.017
1	14.2	13.4	12.6	11.8	11.0	0.016
2	13.8	13.1	12.3	11.5	10.8	0.015
3	13.5	12.7	12.0	11.2	10.5	0.015
4	13.1	12.4	11.7	11.0	10.3	0.014
5	12.8	12.1	11.4	10.7	10.0	0.014
6	12.5	11.8	11.1	10.5	9.8	0.014
7	12.2	11.5	10.9	10.2	9.6	0.013
8	11.9	11.2	10.6	10.0	9.4	0.013
9	11.6	11.0	10.4	9.8	9.2	0.012
10	11.3	10.7	10.1	9.6	9.0	0.012
11	11.1	10.5	9.9	9.4	8.8	0.011
12	10.8	10.3	9.7	9.2	8.6	0.011
13	10.6	10.1	9.5	9.0	8.5	0.011
14	10.4	9.9	9.3	8.8	8.3	0.010
15	10.2	9.7	9.1	8.6	8.1	0.010
16	10.0	9.5	9.0	8.5	8.0	0.010
17	9.7	9.3	8.8	8.3	7.8	0.010
18	9.5	9.1	8.6	8.2	7.7	0.009
19	9.4	8.9	8.5	8.0	7.6	0.009
20	9.2	8.7	8.3	7.9	7.4	0.009
21	9.0	8.6	8.1	7.7	7.3	0.009
22	8.8	8.4	8.0	7.6	7.1	0.008
23	8.7	8.3	7.9	7.4	7.0	0.008
24	8.5	8.1	7.7	7.3	6.9	0.008
25	8.4	8.0	7.6	7.2	6.7	0.008

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**ATTACHMENT C
VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN WATER
AS A FUNCTION OF TEMPERATURE AND SALINITY
PAGE TWO**

Temperature (°C)	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/ 100 mg Chloride
	0	5,000	10,000	15,000	20,000	
26	8.2	7.8	7.4	7.0	6.6	0.008
27	8.1	7.7	7.3	6.9	6.5	0.008
28	7.9	7.5	7.1	6.8	6.4	0.008
29	7.8	7.4	7.0	6.6	6.3	0.008
30	7.6	7.3	6.9	6.5	6.1	0.008
31	7.5					
32	7.4					
33	7.3					
34	7.2					
35	7.1					
36	7.0					
37	6.9					
38	6.8					
39	6.7					
40	6.6					
41	6.5					
42	6.4					
43	6.3					
44	6.2					
45	6.1					
46	6.0					
47	5.9					
48	5.8					
49	5.7					
50	5.6					

Note: In a chloride solution, conductivity can be roughly related to chloride concentration (and therefore, used to correct measured D.O. concentration) using Attachment B.



BROWN & ROOT ENVIRONMENTAL

STANDARD OPERATING PROCEDURES

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Applicability
B&R Environmental, NE

Prepared
Earth Sciences Department

Subject

FIELD SCREENING

Approved
D. Senovich

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1.0 PURPOSE

This section provides an overview of current techniques used to rapidly determine the presence or absence of various target organic compounds at hazardous waste sites. This section also describes the functions and capabilities of available instrumentation and provides suggestions of adapted methods suitable to the use and constraints of mobile laboratories. The purpose of this section is not to establish standardized analytical procedures, but to describe the concepts employed in field screening analyses. The purpose also is to provide guidance in the application of the best methodology practicable, based upon site-specific requirements, with consideration given to native interferences, specific data quality objectives, and variances in available instrumentation.

2.0 SCOPE

Field screening techniques provide for the semi-quantitative analysis of specified compounds by use of portable or transportable instruments based at, or near, a sampling site. Field screening generates Level II data. As such, field screening provides unique information, and it is therefore important to understand the usability of the data generated. Because of the sophistication of the instruments used and the ability to identify specific compounds, field screening analysis should not be confused with non-specific techniques (for example, the process of obtaining total organic readings from portable meters). However, because field screening results are not confirmed (i.e., are generated by non-confirmatory columns and detectors) and are supported by only moderate control criteria, field screening data are not suitable for assessing risk.

The main asset of field screening lies in quick turn-around time and specific (though not confirmed) data, which are suitable for support in field decisions involving, for example, the best placement of well screens, the optimal positioning of monitoring wells, the focusing of sample submissions to fixed-base laboratories (i.e., the selection of samples that will yield the most important information), the delineation of contaminant plumes, the evaluation of unexpected exposures to the field crew, and fundamental regulatory/remedial support. In this manner, field screening allows for decisions to be made on a real-time basis while the field team is mobilized, thus avoiding the several week lag time which occurs when waiting for fixed-base laboratory results.

Field screening techniques are applicable to the analysis of air, soil gas, water and solid matrices for various volatile, semi-volatile, pesticide and PCB compounds. For correlative and quality control purposes, field screening is usually performed in conjunction with a previously established percentage of sample submissions sent to a fixed-base laboratory as split-sample analyses.

3.0 GLOSSARY

Affinity - Molecular attraction

Inert Gas - Non-reactive gas, such as nitrogen or helium, which are both commonly used as purge/carrier gas.

Isothermal - At constant temperature.

Neat - Undiluted.

Suspect - Estimated; of questionable accuracy.

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Target Compound - Of the host of plausible compounds (i.e., compounds that would be recognized by the methodology used), the few compounds chosen for analysis that are felt to be representative of site contamination. Typically, a few compounds are selected and monitored, thus facilitating the analytical effort.

4.0 RESPONSIBILITIES

Field screening-generally consists of two phases:

- An initial survey (pre-screening) using instruments such as OVA meters or HNU detectors to analyze the ambient conditions on site or to conduct limited analyses of samples. Pre-screening generates Level I data. Pre-screening activities may be forfeited if sufficient site historical data exist.
- Mobile laboratory analysis to quickly process a larger number of samples, and to provide specific qualitative and quantitative Level II data.

Personnel and assigned duties essential to the accomplishment of the above two tasks are outlined below:

- Site Manager - Responsible for developing, in consultation with other project personnel (e.g., geologists, chemists, engineers, toxicologists, client), a comprehensive work plan in which pre-screening and screening activities are defined.
- Field Operation Leader - Responsible for the procurement of all necessary equipment and the direct supervision of site activities.
- Sampler - Responsible for conducting pre-screening, if applicable, sampling for submission to the mobile laboratory and fixed-base laboratory, packaging and shipment of samples to the fixed-base laboratory, and the preparation of all necessary paper work associated with sampling and shipment.
- Site Chemist - Responsible for the receipt and analysis of samples submitted to the mobile laboratory for targeted analysis. Responsible for giving guidance in conjunction with the interpretation and appropriate use of the field screening data generated. Responsible for the oversight of analytical QA/QC.
- Health and Safety Officer - Responsible for the development of an appropriate health and safety plan prior to the commencement of site activities. Responsible for the observance of all site operations, for providing assistance and modifying the health and safety plan as necessary to ensure worker protection.

5.0 PROCEDURES

The following subsections discuss methodologies that have been applied successfully in the field screening of environmental samples obtained from hazardous waste sites. These methodologies are not stand-alone protocols and are not intended to serve as standardized analytical procedures. These methodologies are presented as formats within which analytical approaches, based on the referenced established methods, may be developed to fit site specific needs and data quality objectives. It is necessary for the site chemist and the project manager to address the specific modifications to the

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procedures that will be employed and to obtain the necessary approval prior to the commencement of site activities.

5.1 Field Screening of Target Purgeable Volatile Organic Compounds (Aqueous Matrix)

5.1.1 Overview

The following methodology describes a modification of EPA 600 series purge and trap gas chromatographic procedures suitable for the determination of volatile organic contaminants in aqueous matrix samples.¹ Via this methodology, a portion of neat sample or dilution is placed into a glass sparging vessel which is sealed onto a purging device. The contained sample aliquot is subjected to a stream of inert gas which is allowed to bubble through the matrix. This mechanical bubbling action effectively strips the contaminants (now volatilized) from the aqueous matrix and sweeps them onto a packed sorbent tube (i.e., trap), where they are subsequently desorbed (by the action of heat and reverse gas flow) onto a suitable column housed in a pre-programmed gas chromatograph (GC). The contaminants become separated and resolved as they travel through the GC column. Eventually, the contaminants elute through an appropriate detector. The detector signals are processed and interpreted via a previously programmed integrator. Figure 1 provides a list of Potential Volatile Target Compounds.

5.1.2 Summary of Methods

Low Level Analysis - Use of 20 mL neat sample aliquot is suggested in order to achieve reportable detection limits of approximately 5 µg/L. Sample aliquots should be introduced into the sparger using a 10 mL GC syringe. Sample aliquots should not be pipetted, as the action of pipetting may compromise sample integrity due to mechanical stripping.

Medium Level Analysis - Proportioned dilutions may be achieved by using a reduced sample aliquot plus a complementary portion of organic-free water for sparging. For example, a four-fold dilution can be simulated by injecting 5 mL of neat sample plus 15 mL of organic-free water. Similarly, extremely high concentration samples may be analyzed by spiking µL aliquots of neat sample in 19+ mL of organic-free water.

5.1.3 Interferences

Interferences can result from many sources, considering the environmental settings of most hazardous waste sites. However, most interfering impurities are artifacts originating from organic compounds within the specialty gases and the plumbing within the purging mechanism. Interferences in the analytical system are monitored by the analysis of method blanks. Method blanks are analyzed under the same conditions and at the same time as standards and samples, to establish an average background response.

Samples can become contaminated by the diffusion of high concentration contaminants to lower concentrated samples through container seals during shipping and storage. If opted as part of the analysis plan, organic-free trip blanks may be developed and carried by the sampling team together with field samples to assess the existence and the magnitude of this phenomenon.

¹ (EPA Methods 601, 602, 612, and 624).

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FIGURE 1

SUMMARY OF POTENTIAL TARGET COMPOUNDS

(Volatile Organics Analysis)
Acetone
Benzene
Bromoform
Carbon Tetrachloride
Chlorobenzene
Chloroform
Ethylbenzene
Methylene chloride
1,1-Dichloroethene
total 1,2-Dichloroethenes
1,1-Dichloroethane
1,2-Dichloroethane
1,1,1-Trichloroethane
Tetrachloroethene
Toluene
Trichloroethene
Total Dichlorobenzenes
Total Xylenes
2-Butanone (MEK)
4-Methyl-2-pentanone (MIBK)

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Artifacts, which manifest themselves as carryover in the next analytical run, can also occur within the analytical apparatus whenever a highly contaminated sample is introduced. To preclude this from occurring, the sample line and sparge vessel are thoroughly rinsed with organic-free water prior to the bake cycle of each highly contaminated sample run.

5.1.4 Major Apparatus and Materials

Purge and Trap Device - Tekmar Company Model LSC-2 or equivalent complete with a 25 mL glass sparge vessel and a 1/8-inch-O.D. x 25-cm-long stainless steel trap. The trap may be packed solely with Tenax. Alternately, trap packing may consist of 1.0 cm of 3 percent OV-1, 15 cm of Tenax and 8 cm of silica gel. Appropriate trap selection is contingent upon the target compounds being analyzed.

Gas Chromatograph (GC) - Hewlett Packard 5890 or equivalent. The analytical system should be equipped for temperature programming, packed and/or capillary column analysis, and direct-column injection.

Detector - PID/FID or PID/HECD in series; FID only. Optimum detector selection should be based upon the sensitivities of the target compounds being analyzed.

Analytical Column - Glass or stainless steel column packed with 1 percent SP-1000 on 60/80 mesh Carbopack B. Alternatively a suitable capillary column may be used.

Syringes - Assorted: 5 μ L, 25 μ L, 100 μ L, 1 mL, 10 mL.

Volumetric Flasks - 10 mL, 25 mL, 100 mL.

Analytical Balance - Capable of accurately weighing 0.0001 g.

Oven - Constant temperature for the regeneration of contaminated apparatus.

Refrigerators - One dedicated refrigerator each for separate sample and standard storage. Each should be capable of maintaining a stable temperature of 4°C.

5.1.5 Reagents

Methanol - Pesticide grade or equivalent.

Organic-Free Water - Supplied by laboratory or purchased.

Neat Solvents - 96 percent purity, or better, for each compound of interest.

5.1.6 Calibration

Standards - Calibration standards containing the compounds of interest are prepared in methanol by either diluting commercially purchased stock standard mixes or by creating in-house standards from pure solvents. In-house calibration standards are prepared gravimetrically, in that an appropriate μ L aliquot of each target compound is introduced into a known volume of methanol. The appropriate μ L aliquot of compound is based upon the compound's density and response to the selected detector. Calibration standards are created at a level such that a 2-5 μ L spike of standard into 20 mL of organic-free water is suitable for continuing calibration purposes.

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Peak Identification. Compound identities may be substantiated by the analysis of each individual component, thereby documenting compound retention time.

Initial Linearity. An initial three-point calibration curve is generated by the analysis of multiple-aliquot injections of calibration standard. For example, if the calibration standard is created such that a 2 μ L spike into organic-free water yields results at the level of the reported detection limits, a three-point calibration curve may be achieved by the analysis of 2 μ L, 5 μ L, and 10 μ L aliquot spikes. The linearity study for field screening is conducted in such a way as to substantiate the performance of the detector at the level of the reportable limits. It is not performed to demonstrate the entire range of detector capability. The primary objective of field screening is the determination of "clean" versus "dirty" and all results are therefore, considered to be semi-quantitative.

Integration. Calibration of the analytical system is achieved via the external standard method in which response factors (RF) for each compound are obtained by the analysis of a standard mix of known concentration. Following the analysis of this known standard mix, an electronic file is created establishing each peak's identity, retention time, RF, and known concentration. The RF for each target compound is determined by dividing the known concentration by the associated peak response (area or height units). For initial calibration, each compound's average response factor is determined by averaging the peak response results generated for the initial linearity study. These average response factors are programmed into the integrator to allow for direct concentration reading of contaminants found in subsequent sample analyses.

Continuing Calibration. Calibration of the analytical system should be updated three times daily, using the mid-concentration standard: (1) preceding the daily analysis, (2) mid-day and (3) after the daily analyses.

5.1.7 Gas Chromatography

Preconcentration of sample contaminants is achieved through the purge-and-trap process in which stripped volatile contaminants are adsorbed onto a sorbent trap. The affinity the volatilized organic contaminants have for the special packing inside the sorbent tube cause them to be retained within the tube (i.e., adsorbed onto the packing), while other inert components pass through the tube. The purge and trap process consists of a prepurge cycle (optional), a purge cycle (during which contaminants are stripped away from the sample matrix and are trapped within the sorbent tube), a dry purge cycle (optional), a desorb cycle (in which the contaminants are backflushed off the sorbent tube and onto the GC column), and a bake cycle in which the sorbent tube (trap) is heated (with flow) to a high temperature, regenerating of the trap. The selection of the appropriate temperature, options, and duration of the purge and trap processes are contingent upon the target compounds being analyzed. Generally, the following range of conditions apply:

Cycle	Temperature	Duration
Purge	Ambient	8 - 10 minutes
Desorb	180°C	2 - 4 minutes
Bake	215°C	7 - 10 minutes

Desorption of the adsorbed contents of the sorbent trap onto the head of a previously conditioned GC analytical column allows for subsequent analysis by temperature-programmed gas chromatography. The desorbed contaminants are first held at constant temperature (usually in the range of 45-55°C) at the

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head of the analytical column for a period of 3 to 5 minutes. After this initial time period, the GC oven temperature is raised at a constant rate (usually 8-15°C/minute) until a final temperature of 200-225°C is reached. The final temperature is customarily held for a period of 3 to 10 minutes.

The affinity of the volatile contaminants to either the analytical column's mobile or stationary phase, the effect of elevated temperature, and the action of the carrier gas flow through the column cause the volatile contaminants to become separated and resolved, allowing them to elute in bands through the selected detector. As long as the analytical conditions remain constant, each type of volatile component will elute at a characteristic retention time (RT). In this manner, sample contaminants are identified and quantified by comparison to a run of a standard mix containing known compounds concentrations.

Quantitation of volatile contaminants in aqueous matrix samples is calculated based upon the following formula:

$$\text{Concentration sample } (\mu\text{g/L}) = \text{target peak response (sample)} \times \text{RF} \times \text{DF}$$

$$\text{where: RF (Response Factor)} = \frac{\text{Target Concentration Std. } (\mu\text{g/L})}{\text{Target Peak Response Std.}}$$

DF (Dilution Factor) is used when applicable

5.2 Field Screening of Target Purgeable Volatile Organic Compounds (Solid Matrix)

5.2.1 Overview

The following methodology describes a modification of SW846 analytical procedures suitable for the determination of volatile organic contaminants in solid matrix samples.² Via this methodology a portion of sample matrix, or extract, is placed into a glass sparging vessel along with 5-10 mL of organic-free water. The sparge vessel is then sealed onto a purging device. The contained sample (or extract) aliquot is heated while a stream of inert gas is bubbled through the slurry. The mechanical bubbling action effectively strips the contaminants (now volatilized) from the matrix slurry and sweeps them onto a packed sorbent tube (i.e., trap) where they are subsequently desorbed (by action of heat and reverse gas flow) onto a suitable column housed by a pre-programmed gas chromatograph (GC). The volatile contaminants become separated and resolved as they travel through the GC column. Eventually the contaminants elute through an appropriate detector. The detector signals are processed and interpreted by a previously programmed integrator (see Figure 1 for a list of Potential Volatile Target Compounds).

5.2.2 Summary of Methods

Low Level Analysis. Use of a 5 gram sample is suggested to achieve reportable detection limits of approximately 5 µg/kg. The solid matrix (free of obvious pebbles and unrepresentative organic matter) should be quickly measured directly into a tared sparge vessel. After the exact weight of sample is recorded, 5 mL of organic-free water is introduced into the sparger. A heated purge is required.

² (SW846 Methods 5030, 8010, 8015, 8020, 8120, 8240, and 3580).

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Medium Level Analysis. Simple dilutions may be achieved by using a reduced portion of the solid matrix (i.e., 1-<5 grams) and a complementary portion of 9 to 5 mL organic-free water. For example, a 2.5X dilution can be simulated by adding 8 mL of organic-free water to 2 grams of weighed matrix. Moderate to high concentration samples are prepared by extracting a 5 gram portion of solid matrix with 10 mL methanol. A suitable aliquot of the methanol extract (usually 10 μ L to 200 μ L) is then spiked into a sparge vessel containing 10 mL organic-free water. Note that the 1:2 ratio of sample to solvent has introduced a two-fold dilution. The additional dilution factor based upon the μ L injection used must also be taken into consideration.

5.2.3 Interferences

The analysis of volatile organic contaminants in solid matrix samples is susceptible to the same interferences discussed in Subsection 5.1.3. Additionally, some chromatographic artifacts may occur due to impurities present in the methanol used to extract medium/high concentration samples.

5.2.4 Major Apparatus and Materials

In addition to the equipment listed in Subsection 5.1.4, the following devices and materials are required:

Sparge Heater - Tekmar Model 4100 or equivalent. Must be capable of maintaining constant temperature during the purge process.

Pipettes - Assorted glass disposable: 1 mL, 5 mL, 10 mL.

Vials - 15 mL septum-seal for storage of sample extracts.

Vials - 40 mL septum-seal for use in extracting contaminants from sample matrix.

Glass Marking Pen - For labeling vials.

Laboratory Timer - To use during the extraction process.

Aluminum Weighing Pans - For use in determining moisture content of the sample matrix.

5.2.5 Reagents

Methanol - Pesticide grade or equivalent.

Organic-Free Water - Supplied by laboratory or purchased.

Neat Solvents - 96 percent purity or better for each compound of interest.

5.2.6 Calibration

Standard preparation, peak identification, initial linearity, integration, and continuing calibration are accomplished as outlined in Subsection 5.1.6.

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5.2.7 Sample Preparation

Medium to high concentration samples are extracted in methanol prior to chromatographic analysis. The following extraction protocol is suggested:

- Weigh and tare a 40 mL septum-seal vial using an analytical balance.
- Add 5.0 grams of sample matrix to the vial; record weight.
- Pipet a 10 mL volume of methanol into the vial. Assuming 100 percent transference of contaminants from matrix to methanol, note that a 2X dilution factor has been introduced.
- Remove the vial from the analytical balance, cap and shake vigorously for 2 full minutes (alternatively, vial contents may be sonicated).
- Set the vial aside and allow the contents to settle for 5 minutes.
- Pipet off the supernatant extract into a labeled 15 mL vial.
- Perform a gas chromatographic analysis by spiking 10 μ L-200 μ L of the methanol extract into approximately 10 mL organic-free water. Calculate total dilution (deviation) from the original 5 gram sample base.

5.2.8 Gas Chromatography

The same chromatographic theory and GC run conditions outlined in Subsection 5.1.7 are applicable to the volatile organic analysis of solid matrix samples with the following additions:

Prepurge and dry-purge options of the purge and trap process are recommended; a heated purge is required. Sample prepurge enhances subsequent chromatography by allowing air molecules present in the sparge vessel to be replaced by inert purge gas molecules prior to the actual purge cycle. The dry-purge option follows the purge cycle. Dry-purge removes water vapor from the trap tube prior to the desorb cycle. The selection of appropriate purge and trap conditions are contingent upon the target compounds being analyzed. Generally, the following range of conditions apply:

Cycle	Temperature	Duration
Prepurge/Preheat	Ambient/to 40°C	2 minutes/1 minute
Purge	40°C	8 - 10 minutes
Dry-Purge	40°C	2 minutes
Desorb	180°C	3 - 5 minutes
Bake	215°C	7 - 10 minutes

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Due to the extraction process and the need to correct the final value for moisture content, the quantitation of volatile contaminants in solid matrix samples is calculated based upon the following formula:

$$\text{Concentration } (\mu\text{g/kg}) = \text{Sample Peak Response (Area or Height)} \times \text{RF} \times 1/\text{wt. of sample extract(g)} \times \text{final volume (mL)} \times 1\% \text{ solids}$$

$$\text{where: RF (Response Factor)} = \frac{\text{Target Conc. Std. } (\mu\text{g/L})}{\text{Target Peak Response Std.}}$$

$$\% \text{ solids} = 100 - \% \text{ moisture}$$

$$\% \text{ moisture} = \frac{\text{Wet wt.} - \text{Dry wt.}}{\text{Wet wt.}} \times 100$$

The protocol for determining percent moisture is presented in Subsection 5.12.

5.3 Field Screening of Target Semivolatile Organic Compounds (Aqueous Matrix)

5.3.1 Overview

The following methodology describes a modification of SW846 preparative and EPA 600 series analytical gas chromatographic procedures suitable for the determination of semi-volatile contaminants in aqueous matrix samples.³ Via this methodology, a portion of neat sample is extracted using rapid field techniques. An aliquot of sample extract is then directly injected onto an analytical column housed by a previously calibrated gas chromatograph (GC). The semi-volatile compounds are resolved by temperature-programmed gas chromatography and are detected by an FID (Flame Ionization Detector). The detector signals are processed and interpreted via a previously programmed integrator. Figure 2 provides a list of Potential Target Compounds).

5.3.2 Summary of Method

Low Level Analysis - Use of 25 mL neat sample aliquot is suggested. Detection limits vary per each compound sensitivity to the detector. Detection limits of approximately 100 $\mu\text{g/L}$ to 800 $\mu\text{g/L}$ are achievable.

Medium Level Analysis - Proportioned dilutions may be achieved by using a reduced sample aliquot. For example, a five-fold dilution can be simulated by extracting only 5 mL neat sample while retaining the same volume of extraction solvent.

³ (SW846 Methods 3550 and 3580; EPA Methods 604, 605, 610, 611, and 625).

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FIGURE 2

SUMMARY OF POTENTIAL TARGET COMPOUNDS

(Semivolatile Organics Analysis)	
Acenaphthene	Hexachloroethane
Acenaphthylene	Naphthalene
Anthracene	2-Chloronaphthalene
Benzo(a)anthracene	2-Methylnaphthalene
Benzo(a)pyrene	Phenanthrene
total Benzofluoranthenes	Pyrene
Butyl benzyl phthalate	1,2,4-Trichlorobenzene
Chrysene	total Dichlorobenzenes
Diethyl phthalate	Phenol
Dimethyl phthalate	2-Chlorophenol
Di-n-butyl phthalate	2,4-Dichlorophenol
Di-n-octyl phthalate	2,4,5-Trichlorophenol
Fluoranthene	2,4,6-Trichlorophenol
Fluorene	2-Methylphenol
Hexachlorobenzene	4-Methylphenol
Hexachlorobutadiene	2,4-Dimethylphenol
Hexachlorocyclopentadiene	4-Chloro-3-methylphenol

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5.3.3 Interferences

Interferences inherent to this procedure stem from four major sources: (1) impurities present in the solvents used for extraction, (2) system artifacts caused by insufficient column conditioning (3) residual contamination remaining on improperly cleaned glassware and (4) matrix interferences caused by co-extracted organic matter.

Interferences in the analytical system are monitored by the analysis of method blanks. Method blanks are analyzed under the same conditions and at the same time as standards and samples, in order to establish average background response.

Artifacts, which manifest themselves as carryover in the next analytical run, can also occur within the analytical apparatus whenever a highly contaminated sample is introduced. To preclude this from occurring, injection syringes are repeatedly flushed with solvent and the analytical column is baked for a short period of time following each direct injection analysis.

5.3.4 Major Apparatus and Materials

Gas Chromatograph - Hewlett Packard 5890 or equivalent. The analytical system should be equipped for packed or capillary column analysis with a temperature programmable oven and on-column injection capabilities.

Detector - Flame Ionization Detector (FID).

Analytical Column - Better resolution is achieved through use of a capillary column (such a DB-5 or equivalent). However, a packed column, such as 3 percent SP-2250 on 100/120 mesh Supelcoport, is more practical for field use.

Syringes - Assorted: 5 μ L, 25 μ L, 100 μ L, 1 mL.

Analytical Balance - Capable of accurately weighing 0.0001 g.

Vials - 40 mL septum-seal for extraction.

Vials - 2 dram septum-seal for extract storage.

Pipets - Assorted: 1 mL, 5 mL, 10 mL; disposable glass.

Refrigerator - Separate for sample and standard storage. Capable of maintaining a stable temperature of 4°C.

Glass Marking Pen - For labeling vials.

Laboratory Timer - To use during the extraction process.

Hydron Paper - To measure pH.

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5.3.5 Reagents

Methanol - Pesticide grade or equivalent.

Methylene Chloride - Pesticide grade or equivalent.

Sulfuric Acid - 1N, reagent grade.

Neat Standards - 96 percent purity or better for each compound of interest.

5.3.6 Calibration

Standards. Calibration standards containing the compounds of interest are prepared from commercially purchased standard mixes or pure compound. All standards are made and/or diluted using a 1:1 mixture of methylene chloride: methanol and are created for use via a 2 μ L direct injection.

Peak Identification. Compound identities may be substantiated by the analysis of each individual component thereby documenting compound retention time.

Initial Linearity. An initial three point calibration curve is generated by the analysis of multiple-aliquot injections of calibration standard. For example, if the calibration standard is created such that a 2 μ L spike yields results at the level of the reported detection limits, a three-point calibration curve may be achieved by the analysis of 2 μ L, 5 μ L and 10 μ L aliquot spikes.

Calibration. Calibration of the analytical system is achieved via the external standard method, in which response factors (RF) for each compound are obtained by the analysis of a standard mix of known concentration. Following the analysis of this known standard mix, an electronic file is created establishing each peak's identity, retention time, RF and known concentration. The RF for each peak is determined by dividing the known concentration by the peak response (area or height units) of the associated peak. For initial calibration, each compound's average response factor is determined by averaging the peak response results generated for the initial linearity study. These average response factors are programmed into the integrator to allow for direct concentration reading of contaminants found in subsequent sample analyses.

Continuing Calibration. Calibration of the analytical system should be updated three times daily: (1) preceding the daily analyses, (2) mid-day and (3) after the daily analyses. Continuing calibration should be conducted at a concentration level equal to the reported detection limits.

5.3.7 Sample Preparation

All samples must be extracted prior to chromatographic analysis. A suggested protocol follows:

- Pipet 25 mL of aqueous sample matrix each into two 40 mL septum-seal vials; discard pipet.
- Add exactly 2.5 mL of methylene chloride to one of the vial's contents.
- Adjust the pH of the other vial's contents to pH<2 using sulfuric acid.
- Add exactly 2.5 mL methylene chloride to the adjusted contents of the second vial.

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- Cap the vials and shake vigorously for 2 full minutes.
- Set the vials aside and allow the contents to settle for 5 minutes.
- Combine the extracts by pipetting exactly 1.5 mL each of the supernatant extracts into a 2 dram septum-seal vial.
- Gas chromatographic analysis is performed by directly injecting 2-5 μ L of combined sample extract onto the GC's analytical column.

5.3.8 Gas Chromatography

Sample contaminants are first stripped from the matrix by means of methylene chloride extraction (see Subsection 5.3.7). A 2-5 μ L aliquot of the sample extract is introduced onto the head of a previously conditioned analytical column by means of direct injection technique. The semi-volatile contaminants are then resolved by temperature-programmed gas chromatography in which the action of carrier gas flow, elevated temperatures and the affinity each semi-volatile compound has for the phases of the column packing cause the contaminants to separate into bands. As the bands of contaminants elute from the column, they are recognized by an FID (Flame Ionization Detector). Detector signals are then processed by a previously programmed integrator. As long as analytical conditions remain constant, each semivolatile compound will elute at a characteristic retention time (RT). In this manner, sample contaminants are identified and quantified by comparison to a run of standard mix of known concentration.

Under the following run conditions, most compounds of interest will elute within 32 minutes:

Run Parameter	Setting
Initial Column Temperature	100°C
Initial Hold Time	1 minute
Rate	10°C/minute
Final Column Temperature	300°C
Carrier Gas Flow	20 mL/minute

These conditions will need to be adjusted as necessary in order to optimize the resolution of the specific compounds of interest.

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Appropriate quantitation of sample contaminants is based upon the following formula:

$$\text{Concentration } (\mu\text{g/L}) = \text{Target peak response (sample)} \times \text{RF} \times \text{DF}$$

$$\text{where: RF (Response Factor)} = \frac{\text{Target Concentration Std. } (\mu\text{g/L})}{\text{Target Peak Response}}$$

DF (Dilution Factor) is used when applicable

5.4 Field Screening of Target Semivolatile Organic Compounds (Solid Matrix)

5.4.1 Overview

The following methodology describes a modification of SW846 analytical gas chromatographic procedures suitable for the determination of semi-volatile organic contaminants in solid matrix samples.⁴ Via this methodology, a 2 gram portion of a solid sample is extracted using rapid field techniques. An aliquot of the sample extract is then directly injected onto an analytical column for analyses by temperature-programmed gas chromatography. The semi-volatile contaminants are subsequently analyzed by a flame ionization detector (FID). The detector signals are processed by a previously programmed integrator (see Figure 2 for a list of Potential Target Compounds).

5.4.2 Summary of Methods

Low Level Analysis - The extraction of a 2 gram sample portion is suggested to achieve analytical results comparable to approximately 50 mg/kg reportable detection limits.

Medium Level Analysis - Sample dilutions are achieved by diluting a portion of the sample extract (as above) in an appropriate volume of methylene chloride.

5.4.3 Interferences

The analysis of semi-volatile contaminants in solid matrix samples is susceptible to the same interferences discussed in Subsection 5.3.3.

5.4.4 Major Apparatus and Materials

In addition to the equipment listed in Subsection 5.3.4, the following device is required:

Oven - Constant temperature; for use in the determination of moisture content.

⁴ (SW864 Methods 3550 and 3580; 8040; 8060; 8100; 8270; and 8310).

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5.4.5 Reagents

Methanol - Pesticide grade or equivalent.

Methylene Chloride - Pesticide grade or equivalent.

Sulfuric Acid - 1N, reagent grade.

Neat Standards - 96 percent purity or better for each compound of interest.

Anhydrous Sodium Sulfate - Used to remove moisture from the sample matrix.

5.4.6 Calibration

Standard preparation, peak identification, initial linearity, integration and continuing calibration are accomplished as outlined in Subsection 5.3.6.

5.4.7 Sample Preparation

All samples must be extracted prior to chromatographic analysis. A suggested protocol follows:

- Weigh and tare two 40 mL septum-seal vials using an analytical balance.
- Add 2.0 grams of sample matrix (each) to the two vials. Record both sample weights.
- Add approximately 2 grams of anhydrous sodium sulfate to each vial. Mix the vial contents thoroughly using a clean spatula.
- Add exactly 10 mL of methylene chloride to each vial.
- Invert one vial several times to mix. Adjust the pH of this vial's contents to pH<2 using sulfuric acid.
- Cap the vial and shake vigorously for 2 full minutes (alternately, vial contents may be sonicated).
- Set the vials aside and allow the contents to settle for 5 minutes.
- Combine the extracts by pipetting off exactly 1.5 mL each of the supernatant extracts into a labeled 2-dram septum-seal vial.
- Gas chromatographic analysis is performed by directly injecting a 2-5 μ L aliquot of the combined sample extract onto the GC's analytical column.

5.4.8 Gas Chromatography

The same chromatographic theory and GC run conditions outlined in Subsection 5.3.8 are applicable to the semivolatiles analysis of solid matrix samples, with one addition:

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Due to the extraction process and the need to correct the final value for moisture content, the quantitation of semi-volatile contaminants in solid matrix samples is calculated based upon the following formula:

$$\text{Concentration } (\mu\text{g/kg}) = \text{Sample Peak Response (Area or Height)} \times \text{RF} \times 1/\text{wt. of sample extract(g)} \times \text{final volume (mL)} \times 1\% \text{ solids}$$

$$\text{where: RF (Response Factor)} = \frac{\text{Target Conc. Std. } (\mu\text{g/L})}{\text{Target Peak Response Std.}}$$

$$\% \text{ solids} = 100 - \% \text{ moisture}$$

$$\% \text{ moisture} = \frac{\text{Wet wt.} - \text{Dry wt.}}{\text{Wet wt.}} \times 100$$

The protocol for determining percent moisture is presented in Subsection 5.12.

5.5 Field Screening of Organochlorine Pesticides (Aqueous Matrix)

5.5.1 Overview

The following methodology describes a modification of EPA Method 608. This methodology is suitable for the determination of organochlorine pesticide contaminants in aqueous matrix samples. Via this methodology, a portion of neat sample is extracted using rapid field techniques. An aliquot of sample extract is then directly injected onto an analytical column housed in a previously calibrated gas chromatograph (GC). The pesticide contaminants are resolved isothermally and are detected by an electron capture detector (ECD). Detector signals are processed and interpreted via a previously programmed integrator. Figure 3 provides a list of Potential Target Compounds.

5.5.2 Summary of Methods

Low Level Analysis. A 20 mL neat sample aliquot is suggested to achieve method detection limits of approximately 0.5 $\mu\text{g/L}$.

Medium Level Analysis. Proportioned dilutions may be achieved by using a reduced sample aliquot. For example, a five-fold dilution can be simulated by extracting only 4 mL neat sample while retaining the same volume of extraction solvent.

5.5.3 Interferences

Interferences inherent to this procedure stem from four major sources: (1) impurities present in the solvents used for extraction, (2) system artifacts caused by insufficient column conditioning (3) residual contamination remaining on improperly cleaned glassware and (4) matrix interferences caused by co-extracted organic matter.

Interferences in the analytical system are monitored by the analysis of method blanks. Method blanks are analyzed under the same conditions and at the same time as standards and samples, in order to establish average background response.

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FIGURE 3

SUMMARY OF POTENTIAL TARGET COMPOUNDS

(Organochlorine Pesticide Analysis)
Alpha-BHC
Beta-BHC
Delta-BHC
Gamma-BHC (Lindane)
Aldrin
Chlordane
Dieldrin
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Heptachlor
Heptachlor epoxide
4,4-DDD
4,4-DDE
4,4-DDT

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Artifacts, which manifest themselves as carryover in the next analytical run, can also occur within the analytical apparatus whenever a highly contaminated sample is introduced. To preclude this, injection syringes are repeatedly flushed with solvent and the analytical column is baked for a short period of time following each direct injection analysis.

5.5.4 Major Apparatus and Materials

Gas Chromatograph - Hewlett Packard 5890 or equivalent. The analytical system should be equipped for packed or capillary column analysis with isothermal oven and on-column injection capabilities.

Detector - Electron Capture Detector (ECD)

Analytical Column - Glass or stainless steel packed with 1.5 percent SP-2250/1.95 percent SP-2401 on 100/120 mesh Supelcoport. Alternately, a 3 percent OV-1 on 80/100 mesh Supelcoport packed column or a suitable capillary column may be used.

Syringes - Assorted: 5 μ L, 25 μ L, 100 μ L, 1 mL.

Analytical Balance - Capable of accurately weighing 0.0001 g.

Vials - 40 mL septum-seal for extraction.

Vials - 2 dram septum-seal for extract storage.

Glass Marking Pen - For labeling vials.

Laboratory Timer - To use during the extraction process.

Pipets - Assorted: 1 mL, 5 mL, 10 mL; disposable glass.

Refrigerator - Separate for sample and standard storage. Capable of maintaining a stable temperature of 4°C.

5.5.5 Reagents

Hexane - Pesticide grade or equivalent.

Iso-octane - Distilled in glass.

Neat Standards - 96 percent purity or better for each compound of interest.

Zero-Grade Nitrogen - As carrier gas for the gas chromatograph (GC).

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5.5.6 Calibration

Standards. Calibration standards containing the compounds of interest are prepared from commercially purchased standard mixes or pure compound. All standards are made and/or diluted using iso-octane and are created for use via a 2 μ L injection. An example of a working calibration standard within a practical concentration range follows:

Compound	Concentration
Lindane	0.0125 ng/ μ L
Aldrin	0.0250 ng/ μ L
4,4'-DDT	0.0625 ng/ μ L

Peak Identification. Compound identities may be substantiated by the analysis of each individual component thereby documenting compound retention time.

Initial Linearity. An initial three-point calibration curve is generated by the analysis of multiple-aliquot injections of calibration standard. For example, if the calibration standard is created such that a 2 μ L spike yields results at the level of the reported detection limits, a three-point calibration curve may be achieved by the analysis of 2 μ L, 5 μ L, and 10 μ L aliquot spikes.

Calibration. Calibration of the analytical system is achieved via the external standard method in which response factors (RF) for each compound are obtained by the analysis of a standard mix of known concentration. Following the analysis of this known standard mix, an electronic file is created establishing each peak's identity, retention time, RF, and known concentration. The RF for each peak is determined by dividing the known concentration by the peak response (area or height units) of the associated peak. For initial calibration, each compound's average response factor is determined by averaging the peak response results generated for the initial linearity study. These average response factors are programmed into the integrator to allow for direct concentration reading of contaminants found in subsequent sample analyses.

Continuing Calibration. Calibration of the analytical system should be updated three times daily: (1) preceding the daily analysis, (2) mid-day, and (3) after the daily analysis. Continuing calibration should be conducted at a concentration level equal to the reported detection limits.

5.5.7 Sample Preparation

All samples must be extracted prior to chromatographic analysis. Samples are extracted in hexane according to the following suggested protocol:

- Pipet 20 mL aqueous sample matrix into a 40 mL septum-seal vial; discard pipet.
- Add exactly 2.0 mL hexane to the measured matrix aliquot.
- Cap the vial and shake vigorously for 2 full minutes.
- Set the vial aside and allow the contents to settle for 5 minutes.

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- Pipet off the supernatant extract into a labeled 2 dram septum-seal vial.
- Gas chromatographic analysis is performed by directly injecting 2-5 μL of sample extract onto the GC's analytical column.

5.5.8 Gas Chromatography

Sample contaminants are first stripped from the matrix by means of hexane extraction (see Subsection 5.5.7). A 2-5 μL aliquot of the sample extract is introduced onto the head of a previously conditioned analytical column by means of direct injection technique. The organochlorine pesticide compounds are resolved isothermally due to the affinity each compound has for the phases of the column packing as they migrate (under flow) through the analytical column. As the contaminants elute from the column, they are recognized by an electron capture detector (ECD). Detector signals are then processed by a previously programmed integrator. As long as analytical conditions remain constant, each type of organochlorine compound will elute at a characteristic retention time (RT). In this manner, sample contaminants are identified and quantified by comparison to a run of standard mix of known concentration.

Under the following run conditions all commonly targeted organochlorine pesticides will elute within 15 minutes:

Injection Port Temperature	300°C
Isothermal Oven Temperature	215°C
Detector Temperature	350°C
Carrier Gas Flow	70 mL/minute

Appropriate quantitation of sample contaminants is based upon the following formula:

$$\text{Concentration } (\mu\text{g/L}) = \text{Target Peak Response (Sample)} \times \text{RF} \times \text{DF}$$

$$\text{where: RF (Response Factor)} = \frac{\text{Target Concentration Std. } (\mu\text{g/L})}{\text{Target Peak Response Std.}}$$

DF (Dilution Factor) is used when applicable

5.6 Field Screening of Organochlorine Pesticides (Solid Matrix)

5.6.1 Overview

The following methodology describes a modification of SW846 analytical gas chromatographic procedures suitable for the determination of organochlorine pesticide contaminants in solid matrix samples.⁵ Via this methodology, a 5 gram portion of solid sample is extracted using rapid field

⁵ (SW846 Methods 3550, 3580, and 8080).

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techniques. A 2-5 μL aliquot of sample extract is then directly injected onto an analytical column for the isothermal resolution of target compounds. The organochlorine pesticide contaminants are detected by an electron capture detector (ECD). Detector signals are processed and interpreted via a previously programmed integrator.

5.6.2 Summary of Method

Low Level Analysis - Use of a 5 gram portion of sample is suggested to achieve method detection limits of approximately 25 $\mu\text{g/kg}$.

Medium Level Analysis - Sample dilutions are achieved by diluting a portion of the sample extract (as above) in an appropriate volume of iso-octane.

5.6.3 Interferences

The analysis of organochlorine pesticide contaminants in solid matrix samples is susceptible to the same interferences discussed in Subsection 5.5.3.

5.6.4 Major Apparatus and Materials

In addition to the equipment listed in Subsection 5.5.4, the following device is required:

Oven - Constant temperature; for use in the determination of moisture content.

5.6.5 Reagents

Hexane - Pesticide grade or equivalent.

Iso-Octane - Distilled in glass.

Neat Standards - 96 percent purity or better for each compound of interest.

Zero-Grade Nitrogen - As carrier gas for the gas chromatograph (GC).

Anhydrous Sodium Sulfate - Used to remove moisture from the portion of soil prior to extraction.

5.6.6 Calibration

Standard preparation, peak identification, initial linearity, integration and continuing calibration are accomplished as outlined in Subsection 5.5.6.

5.6.7 Sample Preparation

All samples must be extracted prior to chromatographic analysis. A suggested extraction protocol follows:

- Weigh and tare a 40 mL septum-seal vial using an analytical balance.
- Add 5.0 grams of sample matrix to the vial; record weight.

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- Add approximately 3 grams of anhydrous sodium sulfate; mix thoroughly using a clean spatula.
- Pipet exactly 8.0 mL of hexane into the vial.
- Cap the vial and shake vigorously for 2 full minutes (alternately, vial contents may be sonicated).
- Set the vial aside and allow the contents to settle for 5 minutes.
- Pipet off the supernatant extract into a labeled 2 dram septum-seal vial.
- Gas chromatographic analysis is performed by directly injecting 2-5 μ L of sample extract onto the GC's analytical column.

5.6.8 Gas Chromatography

The same chromatographic theory and GC run conditions outlined in Subsection 5.5.8 are applicable to the pesticide analysis of solid matrix samples, with one modification:

Due to the need to correct the final value for moisture content, the quantitation of pesticide contaminants in solid matrix samples is calculated based upon the following formula:

$$\text{Concentration } (\mu\text{g/kg}) = \text{Sample Peak Response (Area or Height)} \times \text{RF} \times 1/\text{wt. of sample extract(g)} \times \text{final volume (mL)} \times 1\% \text{ solids}$$

$$\text{where: } \text{RF (Response Factor)} = \frac{\text{Target Conc. Std. } (\mu\text{g/L})}{\text{Target Peak Response Std.}}$$

$$\% \text{ solids} = 100 - \% \text{ moisture}$$

$$\% \text{ moisture} = \frac{\text{Wet wt.} - \text{Dry wt.}}{\text{Wet wt.}} \times 100$$

The protocol for determining percent moisture is presented in Subsection 5.12.

5.7 Field Screening of Polychlorinated Biphenyl (PCB) Compounds (Aqueous Matrix)

5.7.1 Overview

The following methodology describes a modification of EPA Methods 608 and 625. This methodology is suitable for the determination of polychlorinated biphenyl (PCB) contaminants in aqueous matrix samples. Via this methodology, a portion of neat sample is extracted using rapid field techniques. An aliquot of sample extract is then directly injected onto an analytical column housed by a previously calibrated gas chromatograph (GC). The PCB contaminants are resolved isothermally and are detected by an electron capture detector (ECD). Detector signals are processed and interpreted via a previously programmed integrator (see Figure 4 for a list of Potential Target Compounds).

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FIGURE 4

SUMMARY OF POTENTIAL TARGET COMPOUNDS

(PCB Analysis)
Aroclor-1016
Aroclor-1221
Aroclor-1242
Aroclor-1248
Aroclor-1254
Aroclor-1260

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5.7.2 Summary of Method

Low Level Analysis - A 20 mL neat sample aliquot is suggested to achieve method detection limits of approximately 15 µg/L.

Medium Level Analysis - Proportioned dilutions may be achieved by using a reduced sample aliquot. For example, a five-fold dilution can be simulated by extracting only 4 mL neat sample while retaining the same volume of extraction solvent.

5.7.3 Interferences

Interferences inherent to this procedure stem from four major sources: (1) impurities present in the solvents used for extraction, (2) system artifacts caused by insufficient column conditioning (3) residual contamination remaining on improperly cleaned glassware and (4) matrix interferences caused by co-extracted organic matter.

Interferences in the analytical system are monitored by the analyses of method blanks. Method blanks are analyzed under the same conditions and at the same time as standards and samples, in order to establish average background response.

Artifacts (which manifest themselves as carryover in the next analytical run) can also occur within the analytical apparatus whenever a highly contaminated sample is introduced. To preclude this, injection syringes are repeatedly flushed with solvent and the analytical column is baked for a short period of time following each direct injection analysis.

5.7.4 Major Apparatus and Materials

Gas Chromatograph - Hewlett Packard 5890 or equivalent. The analytical system should be equipped for packed or capillary column analysis with isothermal oven and on-column injection capabilities.

Detector - Electron Capture Detector (ECD).

Analytical Column - Glass or stainless steel packed with 1.5 percent SP-2250/1.95 percent SP-2401 on 100/120 mesh Supelcoport or equivalent. Alternately, a suitable capillary column may be used.

Syringes - Assorted: 5 µL, 25 µL, 100 µL, 1 mL.

Analytical Balance - Capable of accurately weighing 0.0001 g.

Vials - 40 mL septum-seal for sample extraction.

Glass Marking Pen - For labeling vials.

Laboratory Timer - For use during the extraction process.

Vials - 2 dram septum-seal for extract storage.

Pipets - Assorted: 1 mL, 5 mL, 10 mL; disposable glass.

Refrigerator - Separate for sample and standard storage. Capable of maintaining a stable temperature of 4°C.

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5.7.5 Reagents

Hexane - Pesticide grade or equivalent.

Neat Standards - 96 percent purity or better for each compound of interest.

Zero-Grade Nitrogen - As carrier gas for the gas chromatograph (GC).

5.7.6 Calibration

Standards. A singular calibration standard for each PCB compound is prepared from commercially purchased standards or pure compound. All standards are made and/or diluted using hexane and are created for use via a 2 μ L injection. A working calibration standard concentration of 0.375 ng/ μ L for each arochlor is usually practical.

Peak Identification. Each PCB compound is identified by its unique pattern (fingerprint). The identity of each target arochlor is substantiated by the singular analysis of each individual arochlor.

Calibration. Calibration of the analytical system is achieved via the external standard method in which response factors (RF) for each individual arochlor are obtained by the analysis of a standard of known concentration. For each arochlor analyzed, the responses of several peaks characteristic to that particular arochlor are summated. Following the analysis of this known standard, a file is created noting each arochlor's pattern (i.e., the retention times of each characteristic peak), the appropriate RF and known concentration. The RF for each arochlor is determined by dividing the arochlor's known concentration by the summated peak responses (area or height units) which were taken from the associated pattern. The concentration of PCB contaminants in samples is usually hand calculated by manually summing the responses of the characteristic peaks and comparing them to the analogous summated peaks designated in the arochlor standard.

Continuing Calibration - Calibration of the analytical system is performed three times daily: (1) preceding the daily analyses, (2) mid-day and (3) after the daily analyses. Continuing calibration should be conducted at a concentration level equal to the reported detection limits.

5.7.7 Sample Preparation

All samples must be extracted prior to chromatographic analysis. A suggested protocol for hexane extraction follows:

- Pipet 20 mL aqueous sample matrix into a 40 mL septum-seal vial; discard pipet.
- Add exactly 2.0 mL hexane to the measured matrix aliquot.
- Cap the vial and shake vigorously for 2 full minutes.
- Set the vial aside and allow the contents to settle for 5 minutes.
- Pipet off the supernatant extract into a labeled 2-dram septum-seal vial.
- Gas chromatographic analysis is performed by directly injecting 2-5 μ L of sample extract onto the GC's analytical column.

5.7.8 Gas Chromatography

Sample contaminants are first stripped from the matrix by means of hexane extraction (see Subsection 5.7.7). A 2-5 μ L aliquot of the sample extract is introduced onto the head of a previously conditioned analytical column by means of direct injection technique. The PCB compounds are resolved

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isothermally due to the affinity the PCB components have for the phases of the column's packing as they migrate (under flow) through the analytical column. As the contaminants elute from the column, they are recognized by an electron capture detector (ECD). Detector signals are then processed by an integrator. As long as analytical conditions remain constant, each PCB pattern will elute at characteristic retention times (RT). In this manner, sample contaminants are identified and quantified by comparison to a run of standards of known concentration.

The following run conditions have been found to be practical for the analysis of PCB compounds analyzed by field screening techniques:

Run Parameter	Setting
Injection Port Temperature	280°C
Isothermal Oven Temperature	215°C
Detector Temperature	300°C
Carrier Gas Flow	30 mL/minute

Under these conditions, arochlor-1260 will elute within 35 minutes.

Appropriate quantitation of sample contaminants is based upon the following formula:

$$\text{Concentration } (\mu\text{g/L}) = \Sigma \text{ designated peak responses (sample)} \times \text{RF} \times \text{DF}$$

$$\text{where: RF (Response Factor)} = \frac{\text{Concentration standard}}{\Sigma \text{ designated peak responses std.}}$$

DF (Dilution Factor) is used when applicable

5.8 Field Screening of Polychlorinated Biphenyl (PCB) Compounds (Solid Matrix)

5.8.1 Overview

The following methodology describes a modification of SW846 Methods suitable for the determination of polychlorinated biphenyl (PCB) contaminants in solid matrix samples.⁶ Via this methodology, a 5 gram portion of solid sample is extracted using rapid field techniques. A μL aliquot of sample extract is then directly injected onto an analytical column for the isothermal resolution of target components. The PCB pattern is recognized by an electron capture detector (ECD) with detector signals processed by a previously programmed integrator (see Figure 4 for a list of Potential Target Compounds).

5.8.2 Summary of Methods

Low Level Analysis - Use of a 5 gram portion of sample matrix is suggested to achieve method detection limits of approximately 100 $\mu\text{g/kg}$.

⁶ (SW846 Methods 3550, 3580, and 8080).

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Medium Level Analysis - Sample dilutions are achieved by diluting a portion of the sample extract (as above) in an appropriate volume of hexane.

5.8.3 Interferences

Interferences inherent to this procedure stem from four major sources: (1) impurities present in the solvents used for extraction, (2) system artifacts caused by insufficient column conditioning (3) residual contamination remaining on improperly cleaned glassware and (4) matrix interferences caused by co-extracted organic matter.

Interferences in the analytical system are monitored by the analysis of method blanks. Method blanks are analyzed under the same conditions and at the same time as standards and samples, in order to establish average background response.

Artifacts (which manifest themselves as carryover in the next analytical run) can also occur within the analytical apparatus whenever a highly contaminated sample is introduced. To preclude this, injection syringes are repeatedly flushed with solvent and the analytical column is baked for a short period of time following each direct injection analysis.

5.8.4 Major Apparatus and Materials

In addition to the equipment listed in Subsection 5.7.4, the following device is required:

Oven - Constant temperature for use in the determination of moisture content.

5.8.5 Reagents

Methanol - Pesticide grade or equivalent.

Hexane - Pesticide grade or equivalent.

Neat Compounds - 96 percent purity or better for each arochlor of interest.

Organic-Free Water - Laboratory supplied or purchased.

Zero-grade Nitrogen - As carrier gas for the gas chromatograph (GC).

5.8.6 Calibration

Standard preparation, compound identification, integration and continuing calibration are accomplished as outlined in Subsection 5.7.6.

5.8.7 Sample Preparation

All samples must be extracted prior to chromatographic analysis. A suggested protocol for hexane extraction follows:

- Weigh and tare a 40 mL septum-seal vial using an analytical balance.
- Add 5.0 grams of sample matrix to the vial; record weight.

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- Pipet approximately 1.5 mL of organic-free water into the vial. (The water serves as a wetting agent thus facilitating the transference of the PCB compounds from the soil matrix into the methanol.)
- Pipet approximately 2 mL of methanol into the vial.
- Pipet exactly 2.5 mL of hexane into the vial. (By preference, the PCB compounds almost exclusively partition into the hexane.)
- Cap the vial and shake vigorously for 2 full minutes (alternately, vial contents may be sonicated).
- Pipet off the supernatant extract into a labeled 2 dram septum-seal vial.
- Gas chromatographic analysis is performed by directly injecting 2-5 μ L of sample extract onto the GC's analytical column.

5.8.8 Gas Chromatography

The same chromatographic theory and GC run conditions outlined in Subsection 5.7.8 are applicable to the PCB analysis of solid matrix samples, with one modification.

Due to the need to correct the final value for moisture content, the quantitation of PCB contaminants in solid matrix samples is calculated based upon the following formula:

$$\text{Concentration } (\mu\text{g/kg}) = \Sigma \text{ designated peak responses (sample)} \times \text{RF} \times 1/\text{wt. of sample extract(g)} \times \text{final volume (mL)} \times 1\% \text{ solids}$$

$$\text{where: RF (Response Factor)} = \frac{\text{Concentration Standard}}{\Sigma \text{ designated peak responses std.}}$$

$$\% \text{ solids} = 100 - \% \text{ moisture}$$

$$\% \text{ moisture} = \frac{\text{Wet wt.} - \text{Dry wt.}}{\text{Wet wt.}} \times 100$$

The protocol for determining percent moisture is presented in Subsection 5.12.

5.9 Field Screening Analysis of Ambient Air

5.9.1 Overview

The following methodology describes a modification of EPA Compendium methods suitable for the determination of volatile organic contaminants in ambient air.⁷ Via this methodology, an aliquot of gaseous sample is routed through a packed sorbent tube. Volatile contaminants present in the gaseous sample are adsorbed onto the packing within the sorbent tube. The contents of the sorbent tube are

⁷ (EPA Compendium Methods TO-1, TO-2, TO-3, and TO-12).

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subsequently desorbed (by action of heat and reverse gas flow) onto a suitable column housed by a pre-programmed gas chromatograph (GC). The contaminants become separated and resolved as they travel through the GC's column. Eventually, the contaminants elute through an appropriate detector. Detector signals are processed and interpreted via a previously programmed integrator (see Figure 1 for a list of Potential Target Compounds).

5.9.2 Summary of Method

The procedure described here is based upon the analysis of whole air samples collected in canisters or Tedlar bags. However, this procedure can easily be adapted for the analysis of samples collected directly on sorbent tubes or for source sample analysis using aliquot introduction into the GC via direct gaseous injection or an appropriate size commercial sample loop.

5.9.3 Interferences

Interferences can result from many sources, considering the environmental settings of most hazardous waste sites. However, most interfering impurities are artifacts originating from organic compounds within the specialty gases and the plumbing within the trapping/desorption device. Interferences in the analytical system are monitored by the analysis of inert gas method blanks. Method blanks are analyzed under the same conditions and at the same time as standards and samples, to establish an average background response.

5.9.4 Major Apparatus and Materials

Purge and Trap Device - Tekmar Company Model LSC-2 or Model 5000. Traps may be packed solely with Tenax or alternately, trap packing may consist of 1.0 cm of 3 percent OV-1, 15 cm of Tenax and 8 cm of silica gel. Appropriate trap selection is contingent upon the target compounds being analyzed.

Gas Chromatograph - Hewlett Packard 5890 or equivalent. The analytical system should be equipped for temperature programming, packed and/or capillary column analysis and on-column injection.

Detector - PID/FID or PID/HECD in series; FID only. Optimum detector selection should be based upon the sensitivities of the target compounds being analyzed.

Analytical Column - Glass or stainless steel packed with 1 percent SP-1000 on 60/80 mesh Carbopack B. Alternately a suitable capillary column may be used.

Syringes - Assorted: 5 μ L, 25 μ L, 100 μ L, 1 mL, 10 mL.

Volumetric Flasks - 10 mL, 25 mL, 100 mL.

Tedlar Bag - For making gaseous standards.

Flow Meter - For use in measuring the exact volume of gas introduced to the Tedlar.

Analytical Balance - Capable of accurately weighing 0.0001 g.

Vacuum Pump - Low draw, positive seal.

Refrigerator - Separate for sample and standard storage. Capable of maintaining a stable temperature of 4°C.

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5.9.5 Reagents

Methanol - Pesticide grade or equivalent.

Organic-Free Water - Supplied by laboratory or purchased.

Neat Solvents - 96 percent purity or better for each compound of interest.

Ultra-high Purity Nitrogen - For use in generating standards and method blanks.

5.9.6 Calibration

Standards. Calibration standards containing the compounds of interest are prepared in methanol by either diluting commercially purchased stock standard mixes or by creating in-house standards from pure solvents. In-house calibration standards are prepared gravimetrically, in that an appropriate μL aliquot of each target compound is introduced into a known volume of methanol. The appropriate μL aliquot of compound is based upon the compound's density and response to the selected detector. The calibration standards should be created at such a level that a 5-10 μL spike into a 1 liter Tedlar bag filled with nitrogen yields a concentration of 10 $\mu\text{g/L}$ based upon the analysis of a 500 mL aliquot. Aliquots are evacuated onto a clean trap. Alternately, commercially prepared stock calibration gases may be used.

Peak Identification. Compound identities may be substantiated by the analysis of each individual component thereby documenting compound retention time.

Initial Linearity. An initial three-point calibration curve is generated by the trapping and analysis multiple aliquots of calibration standard. For example, if the calibration standard is created such that analysis of a 500 mL aliquot of standard yields results at the level of the reported detection limits, a three-point calibration curve may be achieved by the analysis of 500, 700 and 1,000 mL aliquots.

Integration. Calibration of the analytical system is achieved via the external standard method in which response factors (RF) for each compound are obtained by the analysis of a standard mix of known concentration. Following the analysis of this known standard mix, an electronic file is created establishing each peak's identity, retention time, RF, and known concentration. The RF for each target compound is determined by dividing the known concentration by the associated peak response (area or height units). For initial calibration, each compound's average response factor is determined by averaging the peak response results generated for the initial linearity study. These average response factors are programmed into the integrator to allow for direct concentration reading of contaminants found in subsequent sample analyses.

Continuing Calibration. Calibration of the analytical system should be updated three times daily: (1) preceding the daily analysis, (2) mid-day and (3) after the daily analyses. Continuing calibration should be conducted at a concentration level equal to the reported detection limits.

5.9.7 Gas Chromatography

Preconcentration of sample contaminants is achieved through the trapping process in which the volatile contaminants are adsorbed on to a sorbent trap. The affinity that the volatilized organic contaminants have for the special packing inside the sorbent tube cause them to be retained within the tube (i.e., adsorbed onto the packing) while other components of the gaseous aliquot pass through the tube.

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Desorption of the adsorbed contents of the sorbent trap onto the head of a previously conditioned GC analytical column, allows for subsequent analysis by temperature-programmed gas chromatography. The desorbed contaminants are first held at constant temperature (usually in the range of 45-55°C) at the head of the analytical column for a period of 3-5 minutes. After this initial time period, the GC oven temperature is raised at a constant rate (usually 8-15°C/minute) until a final temperature of 200-225°C is reached. The final temperature is customarily held for a period of 3-10 minutes.

The preferential affinity of the volatile contaminants to either the analytical column's mobile or stationary phase, the effect of elevated temperature and the action of carrier gas flow through the column cause the volatile contaminants to become separated and resolved allowing them to elute in bands through the selected detector. As long as analytical conditions remain constant, each type of volatile component will elute at a characteristic retention time (RT). In this manner, sample contaminants are identified and quantified by comparison to a run of standard of known concentration.

The quantitation of volatile contaminants is calculated based upon the following formula:

$$\text{Concentration sample } (\mu\text{g/L}) = \text{Target peak response (sample)} \times \text{RF} \times \text{DF}$$

$$\text{where: RF (Response Factor)} = \frac{\text{Target concentration standard } (\mu\text{g/L})}{\text{Target peak response std.}}$$

DF (Dilution Factor) is used when applicable

5.10 Field Screening Analysis of Volatile Contaminants in Soil Gas Matrix

5.10.1 Overview

The following methodology describes a modification of SW846 and EPA Compendium methods as applied to the determination of volatile organic contaminants in soil gas.⁸ Via this methodology, a sorbent tube containing previously trapped volatile organic contaminants obtained via the sampling of soil gas matrix, is subsequently desorbed (by action of heat and reverse gas flow) onto a suitable analytical column housed by a pre-programmed gas chromatograph (GC). The volatile organic contaminants become separated and resolved as they travel through the GC's column. Eventually, the contaminants elute through an appropriate detector. Detector signals are processed and interpreted via a previously programmed integrator. Figure 1 provides a list of Potential Target Compounds.

5.10.2 Interferences

Interferences can result from many sources, considering the environmental settings of most hazardous waste sites. However, most interfering impurities are artifacts originating from organic compounds within the specialty gases and the plumbing within the trapping/desorption device. The presence of air molecules and excessive water vapor and/or the degradation of the trap packing can also account for many artifacts.

⁸ (SW846 Method 5040; EPA Compendium Methods TO-1, TO-2, TO-3, and TO-12).

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Interferences in the analytical system are monitored by the analysis of inert gas method blanks. Method blanks are analyzed under the same conditions and at the same time as standards and samples, to establish an average background response.

5.10.3 Major Apparatus and Materials

Purge and Trap Device - Tekmar Company Model LSC-2 or Model 5000. Traps may be packed solely with Tenax or, alternately, trap packing may consist of 10 cm of 3 percent OV-1, 15 cm of Tenax and 8 cm of silica gel. Appropriate trap selection is contingent upon the target compounds being analyzed.

Gas Chromatograph - Hewlett Packard 5890 or equivalent. The analytical system should be equipped for temperature programming, packed and/or capillary column analysis, and on-column injection.

Detector. PID/FID or PID/HECD in series; FID only. Optimum detector selection should be based upon the sensitivity to the detector for the target compounds being analyzed.

Analytical Column. Glass or stainless steel packed with 1 percent SP-1000 on 60/80 mesh Carbopack B. Alternately a suitable capillary column may be used.

Syringes - Assorted gas tight 5 μ L, 25 μ L, 100 μ L, 1 mL, 10 mL.

Volumetric Flasks - 10 mL, 25 mL, 100 mL.

Tedlar Bags - For making gaseous standards.

Flow Meter - For use in measuring the exact volume of gas introduced to the Tedlar bag.

Analytical Balance - Capable of accurately weighting 0.0001 g.

Vacuum Pump - Low draw, positive seal.

Refrigerator - Separate for sample and standard storage. Capable of maintaining a stable temperature of 4°C.

5.10.4 Reagents

Methanol - Pesticide grade or equivalent

Organic-Free Water - Supplied by laboratory or purchased.

Neat Solvents - 96 percent purity or better for each compound of interest.

Ultra-high Purity Nitrogen - For use in generating standards and method blanks.

5.10.5 Calibration

Standard. Calibration standards containing the compounds of interest are prepared in methanol by either diluting commercially purchased stock standard mixes or pure solvents. In-house calibration standards are prepared gravimetrically in that a μ L aliquot of each target compound is introduced into a known volume of methanol. The appropriate μ L aliquot of compound is based upon the compounds density and response to the selected detector. The calibration standards should be created at such a level that

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a 5-10 μL spike into a 1-liter Tedlar bag filled with nitrogen yields a concentration of 10 $\mu\text{g/L}$ based upon the analysis of a 500 mL aliquot. Aliquots are evacuated onto a clean trap. Alternately, commercially prepared stock calibration gases may be used.

Peak Identification. Compound identities may be substantiated by the analysis of each individual component thereby documenting compound retention time.

Initial Linearity. An initial three-point calibration curve is generated by the trapping and analysis of multiple aliquots of calibration standard. For example, if the calibration standard is created such that analysis of a 500 mL aliquot of standard yields results at the level of the reported detection limits, a three-point calibration curve may be achieved by the analysis of 500, 700 and 1,000 mL aliquots.

Integration. Calibration of the analytical system is achieved via the external standard method in which response factors (RF) for each compound are obtained by the analysis of a standard mix of known concentration. Following the analysis of this known standard mix, an electronic file is created establishing each peak's identity, retention time, RF, and known concentration. The RF for each target compound is determined by dividing the known concentration by the associated peak response (area or height units). For initial calibration, each compound's average response factor is determined by averaging the peak response results generated for the initial linearity study. These average response factors are programmed into the integrator to allow for direct concentration reading of contaminants found in subsequent sample analyses.

Continuing Calibration. Calibration of the analytical system should be updated three times daily: (1) preceding the daily analysis, (2) mid-day and (3) after the daily analyses. Continuing calibration should be conducted at a concentration level equal to the reported detection limits.

5.10.6 Sample Preparation

Prior to the desorption and analysis of previously trapped soil gas contaminant tubes, the introduction of a surrogate spike compound via a short purge is recommended. In addition to enhancing quality assurance, this short purge cycle allows inert gas molecules to replace potentially destructive air molecules still entrained within the trap tube. The surrogate spike compound should be introduced to the trap via the following procedure:

- Program the Tekmar LSC-2 device for a 3 minute purge, 3 minute desorb and 8 minute bake cycle.
- Insert a previously trapped soil gas contaminant tube.
- Spike 2 μL of an appropriate surrogate spike solution (such as 1 $\mu\text{g}/\mu\text{L}$ 2-bromo-1-chloropropane) into a glass sparge vessel containing 20 mL organic-free water.
- Purge the surrogate spike onto the trap. Desorb and analyze.

5.10.7 Gas Chromatography

Preconcentration of soil gas matrix contaminants is achieved through the sampling process in which the volatile contaminants are adsorbed onto the sorbent trap. The affinity that the volatile organic contaminants have for the special packing inside the sorbent tube cause them to be retained within the tube (i.e., adsorbed onto the packing) while other components of the gaseous matrix pass through the tube.

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Following the addition of a surrogate spike compound, the adsorbed contents of the sorbent trap are desorbed (by action of heat and reverse gas flow) onto the head of a previously conditioned GC analytical column. The desorbed contaminants are first held at constant temperature (usually between 45-55°C) for an initial time period of 3-5 minutes. The desorbed contaminants are subsequently analyzed by temperature-programmed gas chromatography in which, following the initial hold, the GC oven temperature is raised at a constant rate (usually 8-15°C/minute) until a final temperature of 200-225°C is reached. The final temperature is customarily held for a period of 3-10 minutes.

The preferential affinity of the volatile contaminants to either the analytical column's mobile or stationary phase, the effect of elevated temperature and the action of carrier gas flow through the column cause the volatile contaminants to become separated and resolved allowing them to elute in bands through the selected detector. As long as analytical conditions remain constant, each type of volatile component will elute at a characteristic retention time (RT). In this manner, sample contaminants are identified and quantified by comparison to a run of standard of known concentration.

The quantitation of volatile contaminants is calculated based upon the following formula:

$$\text{Concentration sample } (\mu\text{g/L}) = \text{Target peak response (sample)} \times \text{RF} \times \text{DF}$$

$$\text{where: RF (Response Factor)} = \frac{\text{Target concentration standard } (\mu\text{g/L})}{\text{Target peak response std.}}$$

DF (Dilution Factor) is used when applicable

5.11 Quality Assurance/Quality Control (QA/QC)

5.11.1 Overview

Field screening generates Level II data. As Level II data, the concurrent analysis of laboratory duplicates and matrix spike analyses and the use of surrogate spike compounds is not required. However, beyond the maintenance of practical Standard Operating Procedures (SOPs), certain elements of quality control (if opted) can greatly enhance the interpretation of and the confidence in the data generated. These traditional elements of quality control are discussed here as to how they are adapted to meet the demands of a successfully applied field screening QA/QC program.

The primary purposes of an appropriate QA/QC program are to: (1) substantiate system performance and give credence to the accuracy of the results generated, (2) to define aberrations and give guidance to the interpretation of data, and (3) to achieve these goals through realistic efforts that do not impede the forward progress of the analytical set.

The discussion presented here deals with only direct analytical quality control. Additional elements of QA/QC, such as field duplicate sample submissions, blind spike analysis and external audits are not discussed. Also not discussed are elements of QA/QC that are inherent to good chromatographic technique. Examples of these accepted laboratory practices include (but are not limited to) the following:

- The proper conditioning of analytical columns and traps.
- Use of the solvent flush technique for the creation of standards and for direct injections.
- The appropriate maintenance of selected detectors.

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Details regarding these accepted practices are given in the referenced methodologies.

5.11.2 Holding Times

The primary purpose of field screening is to provide cost-effective, specific data on a near- to real-time turn-around basis. For this reason, samples submitted to the mobile laboratory should be analyzed as soon as possible. Samples awaiting analysis are stored at 4°C in a dedicated refrigerator. If, because of loading, it is not possible to analyze all samples taken daily, the following holding times are suggested:

Type of Sample	Holding Time
VOA (aqueous matrix)	Seven days prior to analysis
VOX (soil matrix)	Ten days prior to analysis
SEMI, PEST, and PCB (aqueous matrix)	Five days prior to extraction; analysis within 30 days
SEMI, PEST, and PCB (soil matrix)	Five days prior to extraction; analysis within 30 days

5.11.3 Sample Sets

Analyses should be conducted in sets of ten, whenever possible, with one laboratory duplicate spike analysis run per set. Each set of sample analyses should be bracketed by the analysis of a standard, with a method blank analysis following each standard run.

The number of analyses per sample set and the associated QA/QC varies per contract. The project work plan should be consulted to verify that all contractual obligations were met.

5.11.4 Continuing Calibration

Standards run for continuing calibration purposes should be analyzed at a level equal to the reported detection limits. Continuing calibration response factors for each parameter should fall within 25 percent D of the average response factor calculated for that particular compound during the initial linearity study (see Figure 5). Data associated with individual parameter not meeting the 25 percent D criteria should be flagged as suspect.

5.11.5 Laboratory Duplicates

One laboratory duplicate should be analyzed per sample set. Laboratory duplicate analyses should generate results within 30 percent RPD (see Figure 5).

5.11.6 Matrix Spike Analyses

Matrix spikes should be conducted at a level of 1-4X the concentration of the reported detection limits. One matrix spike analysis should be run per every 20 samples. Advised recovery ranges vary with respect to the compound being analyzed. Recoveries of 35-150 percent are generally acceptable (see Figure 5).

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FIGURE 5
QC COMPUTATIONS

$$\% \text{ RSD (Relative Standard Deviation)} = \frac{SD}{X} \times 100$$

$$\text{where: } SD = \sqrt{\sum_{i=1}^N \frac{(x_i - \bar{x})^2}{N - 1}}$$

\bar{x} = mean of initial four response factors (per compound)

$$\% \text{ RPD (Relative Percent Difference)} = \frac{D_1 - D_2}{(D_1 + D_2) / 2} \times 100$$

where: D_1 = First Sample Value

D_2 = Second Sample Value

$$\% \text{ D (Percent Difference)} = \frac{X_1 - X_2}{X_1} \times 100$$

where: X_1 = RF (Response Factor) of first result

X_2 = RF of Second Result

$$\% \text{ R (Percent Recovery)} = \frac{SSR - SR}{S} \times 100$$

where: SSR = Spike Sample Results

SR = Sample Result

S = Amount of Spike Added

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5.11.7 Surrogate Spikes

The use of at least one surrogate spike compound is highly recommended. The identity, concentration and addition of the appropriate surrogate spike varies with the procedure being used. Each associated referenced methodology should be consulted for guidance. Surrogate spike recoveries should fall within ± 30 percent (see Figure 5). Sample analyses yielding recoveries outside this 30 percent window should be reanalyzed or the associated data should be flagged as suspect.

5.11.8 Initial Linearity

An initial linearity study is performed as described in each adapted methodology. The associated response factors should all fall within < 20 percent RSD (see Figure 5). Standard runs yielding data that does not meet the < 20 percent RSD criteria should be reanalyzed.

5.11.9 Method Blanks

Method blanks are prepared and analyzed in exactly the same manner as sample matrices. A method blank analysis should follow every standard run and sample of high concentration. Ideally, method blank results should yield no interferences to the chromatographic analysis and interpretation of target compounds. If interferences are present, associated data should be qualified as suspect and/or target detection limits should be adjusted accordingly.

5.11.10 Detection Limits

The appropriate method detection limit (MDL) for an adapted methodology may be statistically calculated using results generated for the initial linearity study and continuing calibrations, or, method detection limits may be substantiated by the analysis of a low standard at the level of the anticipated MDL.

5.12 Supplemental Protocol: Percent Moisture Determination

A moisture correction factor (MCF) is used to adjust the value generated for the amount of contaminant present in a solid matrix sample, so that the value reflects the true (dry weight) concentration of contaminant. Moisture content is determined gravimetrically. The following protocol is suggested for determining percent moisture:

- Mark and weigh an aluminum weighing pan using an analytical balance. Record weight; tare balance.
- Place 5-10 grams of matrix (free from unrepresentative pebbles and organic matter) into the pan; record weight.
- Place the pan and its contents into a drying oven heated to 103°C.
- Dry the matrix for a period of 4-6 hours (or until weight is constant).
- Remove the pan from the oven and allow to cool to room temperature.
- Weigh the pan and record the weight.
- Calculate percent moisture and the MCF.

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5.13 Supplemental Protocol: Field Screening Validation

The validation process serves as an independent check thus ensuring the proper performance of all QA/QC measures. Figures 6 and 7 illustrate a validation protocol that is suitable for the evaluation of field screening data.

6.0 REFERENCES

"Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater," EPA-600/4-82-057. (EPA 600 Series methods):

Method	Title
601	Purgeable Halocarbons
601	Purgeable Aromatics
604	Phenols
606	Phthalate esters
608	Pesticides and PCBs
610	Polynuclear Aromatic Hydrocarbons
612	Chlorinated Hydrocarbons
624	Purgeables
625	Base/Neutrals, Acids, and Pesticides

"Test Methods for the Evaluation of Solid Waste," SW-846, EPA Publication No. 955-001-00000-1. (SW846 preparative methods):

Method	Title
5030	Purge and Trap Technique (Methanol Extraction)
5040	Protocol for Analysis of Sorbent Cartridges
3580	Waste Dilution

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FIGURE 6

BROWN & ROOT ENVIRONMENTAL/FIELD SCREENING

VALIDATION PROTOCOL

1. Verify that samples were handled in sets of ten or less.
2. Verify that at least one laboratory duplicate was run once every ten samples.
3. Verify that one matrix spike analysis was performed once every 20 samples.
4. Ensure that at least one surrogate spike compound was used.
5. Substantiate daily initial calibration table.
6. Determine if at least one standard was run every 8 hours and that a calibration standard was run after every set of 10 samples (plus QC runs).
7. Check standard tracking form to ensure that parameter response factors fall within 25 percent of the initial calibration. If parameters exceed 25 percent value, check to see how problem was corrected and verify all reported results for that parameter were flagged as suspect.
8. Check that method blanks were run after every calibration and every sample of high concentration. Verify that any system artifacts were tracked and reported.
9. Verify that reported detection levels have been properly substantiated.
10. Evaluate chromatograms of target compound peaks for proper identification. (Check peak shapes and shoulders.)
11. Check quantitations of approximately 20 percent of samples.
12. Verify if statistics have been calculated for the data package.
13. Verify retention time window.
14. Determine if each chromatogram reports the following information:
 - a. Sample name/number
 - b. Date/time of analysis
 - c. Laboratory duplicate designation (if applicable)
 - d. Matrix spike designation (if applicable)
 - e. Concentration/dilution value recorded (if applicable)
 - f. Retention time reported at apex of each peak
 - g. Chromatographic report generated includes peak name, retention time, peak area or peak height.

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FIGURE 6
BROWN & ROOT ENVIRONMENTAL/FIELD SCREENING
VALIDATION PROTOCOL
PAGE TWO

15. Verify that package Operations Record contains the following information:
 - a. Purge, desorb, and bake time of sample concentrator
 - b. GC flow rate, attenuation, range, initial temperature, initial time, ramp, final temperature, final time; injection temperature and detector temperature.
16. Verify that chain of custody was maintained.
17. Verify that package narrative relates all pertinent information necessary to properly interpret results.

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FIGURE 7

BROWN & ROOT ENVIRONMENTAL/FIELD SCREENING

VALIDATION RECORD

Project Name/Number: _____ Sample Matrix: _____

Dates Samples Received: _____ Data Reviewer: _____

Dates Samples Analyzed: _____ Data Reviewed: _____

Evaluation Checklist:

_____ Data Completeness	_____ Duplicate Analyses Results
_____ Calibration Records	_____ Matrix Spike Recoveries
_____ Method Blank Analyses	_____ Compound Identification
_____ Surrogate Spike Results	_____ Detection Limits Achieved

Reviewer's Evaluation	Volatiles	Acids	Base/Neutrals	PCBs/Pesticides
Acceptable				
Acceptable with Exception(s)				
Questionable				
Unacceptable				

Validator's Comments:

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"Test Methods for the Evaluation of Solid Waste," SW846, EPA Publication No. 955-001-00000-1. (SW846 analytical methods):

Method	Title
8010	Halogenated Volatile Organics
8015	Non-halogenated Volatile Organics
8020	Aromatic Volatile Organics
8040	Phenols
8060	Phthalate Esters
8080	Organochlorine Pesticides and PCBs
8100	Polynuclear Aromatic Hydrocarbons
8120	Chlorinated Hydrocarbons
8240	GC/MS for Volatile Organics
8250	GC/MS for Semi-volatile Organics (Packed Column)
8270	GC/MS for Semi-volatile Organics (Capillary Column)
8310	Polynuclear Aromatic Hydrocarbons

"Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air," EPA-600/4-84-041.

Method	Title
TO-1	Tenax GC Adsorption
TO-2	Carbon Molecular Sieve Adsorption
TO-3	Cryogenic Trapping
TO-12	NMOC in Ambient Air Using Preconcentration and FID

"Field Measurement of PCBs in Soil and Sediment Using a Portable Gas Chromatograph," Spittler, Dr. Thomas. U.S. EPA Region I.

"Comparability of Field Screening Data to Fixed-base Laboratory Results," Scheib, Debra A., Dr. H. Roffman and C. Kieda. NUS Corporation.

"Manual of Field Analytical Technique," Scheib, Debra A. NUS Corporation.

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7.0 RECORDS

A formalized system for tracking and reporting information is essential to appropriately document the specific analytical approach used to support the investigation of a hazardous waste site. Sound record keeping practices serve to:

- Document the QA/QC measures performed.
- Substantiate sample integrity.
- Present data in a usable form.
- Organize and record the occurrences pertinent to the interpretation of the data generated.
- Function as the historical record leading to the development of new methodologies and for the improvement of existing methods.

In light of the advances in laboratory automation and computer technology, record keeping can take the form of either electronic file or bench data sheets. Regardless of the method of record keeping employed while in the field, the submission (to the Project Manager) of a formalized, hard-copy data package upon conclusion of the field screening activity is strongly recommended. Examples of useful bench data sheets not already presented in this text follow as Figures 8 through 20. A suggested Table of Contents (Figure 21) and data package Cover Sheet (Figure 22) are also presented.

Mobile laboratory facilities vary greatly in design. Consequently, in addition to the maintenance of pertinent records, a trailer-specific S.O.P. (Standard Operating Procedure) should be developed to provide the following:

- Specific information regarding the operation and maintenance of the particular affiliated instrumentation.
- Guidance regarding the hook-up of power and telephone service.
- Procedures addressing the disposal of laboratory waste.
- Materials and supply resources.
- Towing and transport considerations.
- Housekeeping requirements.

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FIGURE 9

BROWN & ROOT ENVIRONMENTAL/FIELD SCREENING

DATA QUALIFIERS

- B - found in blank
- DL - detection limit
- DNI - peak "did not integrate;" quantitation is not possible
- J - estimated quantity
- u - compound analyzed for but value generated is below reported DL
- ↑ - GC peak over range. Peak exceeds linear range of detector and is not quantifiable
- () - compound present, but detected at levels below the reported DL

CHROMATOGRAM NOTATIONS

- ART - artifact; peak produced by chromatographic system, not caused by sample content
- au - area units
- D - laboratory duplicate
- hu - height units
- MB - method blank
- MS - matrix spike
- NEAT - sample is not diluted
- FD - field duplicate

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FIGURE 10

BROWN & ROOT ENVIRONMENTAL/FIELD SCREENING OPERATIONS RECORD

General Information:

Date(s)	_____	Task Name	_____	Std Used	_____
Site Name	_____	Task No.	_____	Analyst	_____
Site No.	_____	Matrix	_____		

Chromatographic Programming:

Flow	_____	In. Temp.	_____	Inj. Temp.	_____
Attn	_____	In. Time	_____	Det. Temp.	_____
Range	_____	Rate	_____	Other	_____
Col.	_____	Fin. Temp.	_____		
Detector	_____	Fin. Time	_____		

Integration System:

File	_____	Speed	_____	Other	_____
Attn	_____	Zero/Slope	_____		
Range	_____	Min. Area	_____		
Method	_____	Stop Time	_____		
Format	_____				

Purge/Desorption System:

Purge Time	_____	SP-2	_____	Prepurge	_____
Desorb	_____	SP-3	_____	Preheat	_____
Bake Time	_____	SP-4	_____	Purge Temp.	_____
SP-1	_____	SP-5	_____	Line Temp.	_____

Comments:

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FIGURE 11
BROWN & ROOT ENVIRONMENTAL/FIELD SCREENING
ANALYTICAL STANDARDS LOG

Target Compound	Desired Final Concentration*	Matrix Amount	Required Dose	Desired Standard Injection	Required Standard Concentration	Volume of Standard	Compound Density	Calculation	Amount Neat Compound
Example: Trichloroethene	3 ppb	20 mL	0.06 $\mu\text{g/L}$	2 μL	0.03 $\mu\text{g}/\mu\text{L}$	50,000 μL	1,465 $\mu\text{g}/\mu\text{L}$	$\mu\text{L} = \{0.03 \mu\text{g}/\mu\text{L} \times 50,000 \mu\text{L}\} + 1,465 \mu\text{g}/\mu\text{L}$	1.02

*Example: $\frac{3 \mu\text{g}}{\text{L}} = \frac{3 \mu\text{g}}{1,000 \text{ mL}} = 0.06 \mu\text{g per 20 mL}$

Therefore, 0.06 μg per 2 μL injection of standard.

Therefore, standard concentration must equal 0.03 $\mu\text{g}/\mu\text{L}$.

Formula: Neat Solvent (μL) = $\frac{\text{Required Std. Concentration } (\mu\text{g/L}) \times \text{Volume of Std. } (\mu\text{L})}{\text{Compound Density } (\mu\text{g}/\mu\text{L})}$

Check: $1.02 (\mu\text{L}) \times \frac{1,494 \mu\text{g}}{\mu\text{L}} = \frac{1,494 \mu\text{g}}{5,000 \mu\text{L}} \times 2 \mu\text{L} = \frac{0.0598 \mu\text{g}}{20 \text{ mL}} \times \frac{1,000 \text{ mL}}{\text{L}} = 2.99 \text{ ppb}$

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FIGURE 15
BROWN & ROOT ENVIRONMENTAL/FIELD SCREENING

METHOD BLANK SUMMARY (OVERVIEW)

By definition, method blanks consist of an equal aliquot of like matrix + surrogate spike. For quality control/troubleshooting purposes, it sometimes becomes necessary to exclude the surrogate spike or run variations of the matrix. In order to avoid confusion, distinctions of various types of blanks are clarified here:

Trip Blank - previously prepared VOA vials filled with organic-free water, sealed and transported with sample containers. These sealed vials are not opened until analysis; their purpose is to ensure no cross contamination (migration of contaminants through the container's seal) has occurred during transit.

Field Blank - sometimes referred to as "Decon Rinsate." A containerized aliquot of bailer or sampler washwater. Ensures appropriate cleaning and rinsing of the sampling equipment.

Prepared Soil Matrix Blank - laboratory soil matrix is prepared by obtaining an amount of earth and baking it in the drying oven overnight at 105°C to drive off volatile organic compounds. An aliquot of prepared matrix is run without surrogate spike to ensure the matrix is free of contaminants.

Aqueous Method Blank - an aliquot of organic-free water + surrogate spike.

Solid Method Blank - an aliquot of prepared soil matrix + surrogate spike.

Water Purge (System Blank) - an aliquot of organic-free water only; no surrogate spike.

Repurge - repurging, trapping and analysis of material run previously in sparging apparatus.

Desorption/Redesorption - desorb and analysis of trap without any additional purging.

GC Column Only - analysis of GC column response without any prior desorption onto the GC.

Comments regarding the various blank analyses performed for this site appear on the following summary sheets:

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**FIGURE 16
BROWN & ROOT ENVIRONMENTAL/FIELD SCREENING**

METHOD BLANK SUMMARY

FRACTION: _____ MATRIX: _____

DATE ANALYZED: _____ BY: _____

INSTRUMENT: _____

Compounds Found	Concentrations	Detection Limit

Comments: _____

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FIGURE 17
BROWN & ROOT ENVIRONMENTAL/FIELD SCREENING
LABORATORY DUPLICATE SUMMARY

Sample Number: _____

Matrix: _____

Chromatogram Number: _____

Compound	Original Result	Duplicate Result	Percent Difference

$$\text{Percent Difference} = \frac{\text{Original} - \text{Duplicate}}{1/2 \text{ Original} + \text{Duplicate}} \times 100\%$$

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FIGURE 21
BROWN & ROOT ENVIRONMENTAL/FIELD SCREENING
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- B. Project summary report
- C. Data qualifiers

SECTION II

- A. Sample chromatograms
- B. Operations record
- C. Percent moisture determinations

SECTION III

- A. Standard chromatogram
- B. Analytical standards log
- C. 3-Point initial calibration
- D. continuing calibration summary
- E. Method blank overview and summary
- F. Method blank chromatograms

SECTION IV

- A. Duplicate summary
- B. Matrix spike summary
- C. Run roster
- D. Supplemental support data
 - Quantitations
 - Surrogate recoveries

SECTION V

- A. Shipping data
- B. Communications notes
- C. Analytical methodology

SECTION VI

- A. Validation procedure
- B. Validation record

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**FIGURE 22
COVER SHEET**

BROWN & ROOT ENVIRONMENTAL/FIELD SCREENING

Project Number/Name: _____

Analysis/Matrix: _____

Dates: _____

File ____ of ____



BROWN & ROOT ENVIRONMENTAL

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Applicability
B&R Environmental, NE

Prepared
Earth Sciences Department

Subject

NON-RADIOLOGICAL SAMPLE HANDLING

Approved
D. Senovich

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to provide information on sample preservation, packaging, and shipping procedures to be used in handling environmental samples submitted for chemical constituent, biological, or geotechnical analysis. Sample chain-of-custody procedures and other aspects of field documentation are addressed in SOP SA-6.3. Sample identification is addressed in SOP CT-04.

2.0 SCOPE

This procedure:

- Describes the appropriate containers to be used for samples depending on the analyses to be performed, and the steps necessary to preserve the samples when shipped off site for chemical analysis.
- Provides instruction for sample packaging and shipping in accordance with current U.S. Department of Transportation (DOT) regulations.

3.0 GLOSSARY

Hazardous Material - A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. Under 49 CFR, the term includes hazardous substances, hazardous wastes, marine pollutants, and elevated temperature materials, as well as materials designated as hazardous under the provisions of §172.101 and §172.102 and materials that meet the defining criteria for hazard classes and divisions in Part 173.

Hazardous Waste - Any substance listed in 40 CFR, Subpart D (y261.30 et seq.), or otherwise characterized as ignitable, corrosive, reactive, or toxic (as defined by Toxicity Characteristic Leaching Procedure, TCLP, analysis) as specified under 40 CFR, Subpart C (y261.20 et seq.), that would be subject to manifest requirements specified in 40 CFR 262. Such substances are defined and regulated by EPA.

Marking - A descriptive name, identification number, instructions, cautions, weight, specification or UN marks, or combination thereof required on outer packaging of hazardous materials.

n.o.i - Not otherwise indicated (may be used interchangeably with n.o.s.).

n.o.s. - Not otherwise specified.

ORM - Other regulated material (see DOT 49 CFR 173.144).

Packaging - A receptacle and any other components or materials necessary for compliance with the minimum packaging requirements of 49 CFR 174, including containers (other than freight containers or overpacks), portable tanks, cargo tanks, tank cars, and multi-unit tank-car tanks to perform a containment function in conformance with the minimum packaging requirements of 49 CFR 173.24(a) & (b).

Placard - Color-coded, pictorial sign which depicts the hazard class symbol and name and which is placed on the side of a vehicle transporting certain hazardous materials.

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Common Preservatives:

- Hydrochloric Acid - HCl
- Sulfuric Acid - H₂SO₄
- Nitric Acid - HNO₃
- Sodium Hydroxide - NaOH

Other Preservatives

- Zinc Acetate
- Sodium Thiosulfate - Na₂S₂O₃

Normality (N) - Concentration of a solution expressed as equivalent per liter, an equivalent being the amount of a substance containing 1 gram-atom of replaceable hydrogen or its equivalent. Thus, a one-molar solution of HCl, containing 1 gram-atom of H, is "one normal," whereas a one-molar solution of H₂SO₄, containing 2 gram-atoms of H, is "two normal."

Reportable Quantity (RQ) - For the purposes of this SOP, means the quantity specified in column 3 of the Appendix to DOT 49 CFR §172.101 for any material identified in column 1 of the appendix. A spill greater than the amount specified must be reported to the National Response Center.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the location and time of collection.

4.0 RESPONSIBILITIES

Field Operations Leader - Directly responsible for the bottling, preservation, labeling, packaging, shipping, and custody of samples up to and including release to the shipper.

Field Samplers - Responsible for initiating the Chain-of-Custody Record (per SOP SA-6.3), implementing the packaging and shipping requirements, and maintaining custody of samples until they are relinquished to another custodian or to the common carrier.

5.0 PROCEDURES

Sample identification, labeling, documentation, and chain-of-custody are addressed by SOP SA-6.3.

5.1 Sample Containers

Different types of chemicals react differently with sample containers made of various materials. For example, trace metals adsorb more strongly to glass than to plastic, whereas many organic chemicals may dissolve various types of plastic containers. Attachments A and B show proper containers (as well as other information) per 40 CFR 136. In general, the sample container shall allow approximately 5-10 percent air space ("ullage") to allow for expansion/vaporization if the sample warms during transport. However, for collection of volatile organic compounds, head space shall be omitted. The analytical laboratory will generally provide certified-clean containers for samples to be analyzed for chemical constituents. Shelby tubes or other sample containers are generally provided by the driller for samples requiring geotechnical analysis. Sufficient lead time shall be allowed for a delivery of bottle orders. Therefore, it is critical to use the correct container to maintain the integrity of the sample prior to analysis.

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Once opened, the container must be used at once for storage of a particular sample. Unused but opened containers are to be considered contaminated and must be discarded; because of the potential for introduction of contamination, they cannot be reclosed and saved for later use. Likewise, any unused containers which appear contaminated upon receipt, or which are found to have loose caps or a missing Teflon liner (if required for the container), shall be discarded.

5.2 Sample Preservation

Many water and soil samples are unstable and therefore require preservation to prevent changes in either the concentration or the physical condition of the constituent(s) requiring analysis. Although complete and irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that inevitably take place after the sample is collected. Preservation techniques are usually limited to pH control, chemical addition(s), and refrigeration/ freezing (certain biological samples only).

5.2.1 Overview

The preservation techniques to be used for various analytes are listed in Attachments A and B. Reagents required for sample preservation will either be added to the sample containers by the laboratory prior to their shipment to the field or be added in the field (in a clean environment). Only high purity reagents shall be used for preservation. In general, aqueous samples of low-concentration organics (or soil samples of low- or medium-concentration organics) are cooled to 4°C. Medium-concentration aqueous samples and high-hazard organics samples are typically not preserved. Low-concentration aqueous samples for metals are acidified with HNO₃, whereas medium-concentration and high-hazard aqueous metal samples are not preserved. Low- or medium-concentration soil samples for metals are cooled to 4°C, whereas high-hazard samples are not preserved.

The following subsections describe the procedures for preparing and adding chemical preservatives. Attachments A and B indicate the specific analytes which require these preservatives.

5.2.2 Preparation and Addition of Reagents

Addition of the following acids or bases may be specified for sample preservation; these reagents shall be analytical reagent (AR) grade or purer and shall be diluted to the required concentration with deionized water before field sampling commences. To avoid uncontrolled reactions, be sure to Add Acid to water (not vice versa). A dilutions guide is provided below.

Acid/Base	Dilution	Concentration	Estimated Amount Required for Preservation
Hydrochloric Acid (HCl)	1 part concentrated HCl: 1 part double-distilled, deionized water	6N	5-10 mL
Sulfuric Acid (H ₂ SO ₄)	1 part concentrated H ₂ SO ₄ : 1 part double-distilled, deionized water	18N	2 - 5 mL
Nitric Acid (HNO ₃)	Undiluted concentrated HNO ₃	16N	2 - 5 mL
Sodium Hydroxide (NaOH)	400 grams solid NaOH dissolved in 870 mL double-distilled, deionized water; yields 1 liter of solution	10N	2 mL

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The amounts required for preservation shown in the above table assumes proper preparation of the preservative and addition of the preservative to one liter of aqueous sample (assuming that the sample is initially at pH 7, is poorly buffered, and does not contain particulate matter; as these conditions vary, more preservative may be required). Consequently, the final sample pH must be checked using narrow-range pH paper, as described in the generalized procedure detailed below:

- Pour off 5-10 mL of sample into a dedicated, clean container. Use some of this sample to check the initial sample pH using wide range (0-14) pH paper. Never dip the pH paper into the sample; always apply a drop of sample to the pH paper using a clean stirring rod or pipette.
- Add about one-half of the estimated preservative required to the original sample bottle. Cap and invert gently several times to mix. Check pH (as described above) using medium range pH paper (pH 0-6 or pH 7.5-14, as applicable).
- Cap sample bottle and seal securely.

Additional considerations are discussed below:

- To test if ascorbic acid must be used to remove oxidizing agents present in the sample before it can be properly preserved, place a drop of sample on KI-starch paper. A blue color indicates the need for ascorbic acid addition.

If required, add a few crystals of ascorbic acid to the sample and retest with the KI-starch paper. Repeat until a drop of sample produces no color on the KI-starch paper. Then add an additional 0.6 grams of ascorbic acid per each liter of sample volume.

Continue with proper base preservation of the sample as described, generally, above.

- Samples for sulfide analysis must be treated by the addition of 4 drops (0.2 mL) of 2N zinc acetate solution per 100 ml of sample.

The 2N zinc acetate solution is made by dissolving 220 grams of zinc acetate in 870 mL of double-distilled, deionized water to make 1 liter of solution.

The sample pH is then raised to 9 using the NaOH preservative.

- To test if sodium thiosulfate must be added to remove residual chlorine from a sample, test the sample for residual chlorine using a field test kit especially made for this purpose.

If residual chlorine is present, add 0.08 grams of sodium thiosulfate per liter of sample to remove the residual chlorine.

Continue with proper acidification of the sample as described, generally, above.

For biological samples, 10% buffered formalin or isopropanol may also be required for preservation. Questions regarding preservation requirements should be resolved through communication with the laboratory before sampling begins.

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5.3 Field Filtration

At times, field-filtration may be required to provide for the analysis of dissolved chemical constituents. Field-filtration must be performed prior to the preservation of samples as described above. General procedures for field filtration are described below:

- The sample shall be filtered through a non-metallic, 0.45-micron membrane filter, immediately after collection. The filtration system shall consist of dedicated filter canister, dedicated silicon tubing, and a peristaltic pump with pressure or vacuum pumping squeeze action (since the sample is filtered by mechanical peristalsis, the sample travels only through the tubing).
- To perform filtration, thread the silicon tubing through the peristaltic pump head. Attach the filter canister to the discharge end of the silicon tubing (note flow direction arrow); attach the aqueous sample container to the intake end of the silicon tubing. Turn the peristaltic pump on and perform filtration.
- Continue by preserving the filtrate (contained in the filter canister), as applicable and generally described above.

5.4 Sample Packaging and Shipping

Samples collected for shipment from a site shall be classified as either environmental or hazardous material samples. Samples from drums containing materials other than Investigative Derived Waste (IDW) and samples obtained from waste piles or bulk storage tanks are generally shipped as hazardous materials. A distinction must be made between the two types of samples in order to:

- Determine appropriate procedures for transportation of samples (if there is any doubt, a sample shall be considered hazardous and shipped accordingly.)
- Protect the health and safety of transport and laboratory personnel receiving the samples (special precautions are used by the shipper and at laboratories when hazardous materials are received.)

Detailed procedures for packaging environmental and hazardous material samples are outlined in the remainder of this section.

5.4.1 Environmental Samples

Environmental samples are packaged as follows:

- Place sample container, properly identified and with lid securely fastened in a plastic bag (e.g. Ziploc baggie), and seal the bag.
- Place sample in a cooler constructed of sturdy material which has been lined with a large, plastic (e.g. "garbage" bag).
- Pack with enough noncombustible, absorbent, cushioning materials such as vermiculite (shoulders of bottles must be iced if required) to minimize the possibility of the container breaking.

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- If cooling is required (see Attachments A and B), double-bag ice in Ziploc baggies and place around container shoulders, and on top of absorbent packing material (minimum of 8 pounds of ice for a medium-size cooler).
- Seal (i.e., tape or tie top in knot) large liner bag.
- The original (top, signed copy) and extra carbonless copies of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the first cooler. The COC form should then state how many coolers are included with that shipment.
- Close and seal outside of cooler as described in SOP SA-6.3. Signed custody seals must be used.

Coolers must be marked as containing "Environmental Samples." The appropriate side of the container must be marked "This End Up" and arrows placed appropriately. No DOT marking or labeling is required; there are no DOT restrictions on mode of transportation.

5.4.2 Determination of Shipping Classification for Hazardous Material Samples

Samples not determined to be environmental samples, or samples known or expected to contain hazardous materials, must be considered hazardous material samples and transported according to the requirements listed below.

5.4.2.1 Known Substances

If the substance in the sample is known or can be identified, package, mark, label, and ship according to the specific instructions for that material (if it is listed) in the DOT Hazardous Materials Table, 49 CFR 172.101. (DOT Guide for shippers can be found in Attachment D of this document.)

To determine the proper shipping name, use the following steps to help locate the shipping name on the Hazardous Materials Table, DOT 49 CFR 172.101.

1. Look first for the chemical or technical name of the material, for example, ethyl alcohol. Note that many chemicals have more than one technical name, for example, perchloroethylene (not listed in 172.101) is listed as tetrachloroethylene (listed 172.101). It may be useful to consult a chemist for all possible technical names a material can have. If your material is not listed by its technical name, then . . .
2. Look for the chemical family name. For example, pentyl alcohol is not listed but the chemical family name is: alcohol, n.o.s. (not otherwise specified). If the chemical family name is not listed, then . . .
3. Look for a generic name based on end use. For example, Paint, n.o.s or Fireworks, n.o.s. If a generic name based on end use is not listed, then . . .
4. Look for a generic family name based on end use, for example, drugs, n.o.s. or cosmetics, n.o.s. Finally, if your material is not listed by a generic family name but you suspect or know the material is hazardous because it meets the definition of one or more hazardous classes, then . . .

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5. You will have to use the general hazard class for a proper shipping name. For example, Flammable Liquid, n.o.s. or Oxidizer, n.o.s.

5.4.2.2 Unknown Substances

For samples of hazardous substances of unknown content, select the appropriate transportation category according to the DOT hazardous materials classification of a material having more than one hazard. This procedure is outlined in DOT Regulation 49 CFR 173.2a. (This can be found in Attachment C of this SOP.)

The correct shipping classification for an unknown sample is selected through a process of elimination, as outlined in DOT Regulation 49 CFR 172.101(c)(11). By using the provisions in this paragraph, the proper shipping name and description will be determined. A step-by-step guide is provided by the Department of Transportation (DOT) and can be found in Attachment D of this SOP.

5.4.3 **Packaging and Shipping of Samples Classified as Flammable Liquid (or Solid)**

5.4.3.1 Packaging

Applying the word "flammable" to a sample does not imply that it is in fact flammable. The word prescribes the class of packaging according to DOT regulations.

1. Containerize sample as required (see Attachments A and B). To prevent leakage, fill container no more than 90 percent full. Seal lid with teflon tape or wire.
2. Complete sample label and attach securely to sample container.
3. Seal container and place in 2-mil-thick (or thicker) polyethylene bag (e.g., Ziploc baggie), one sample per bag. Position sample identification label so that it can be read through bag. Seal bag.
4. For soil jars, place sealed bag inside metal can (available from laboratory or laboratory supplier) and cushion it with enough noncombustible, absorbent material (for example, vermiculite or diatomaceous earth) between the bottom and sides of the can and bag to prevent breakage and absorb leakage. Pack one bag per can. Use clips, tape, or other positive means to hold can lid securely, tightly and permanently. Mark can as indicated in Paragraph 1 of Section 5.3.4.2, below. Single 1-gallon bottles do not need to be placed in metal cans.
5. Place one or more metal cans (or a single 1-gallon bottle) into a strong outside container, such as a metal picnic cooler or a DOT-approved fiberboard box. Surround cans (or bottle) with noncombustible, absorbent cushioning materials for stability during transport. The absorbent material should be able to absorb the entire contents of the container. Mark container as indicated in Paragraph 2 below.

5.4.3.2 Marking/Labeling

1. Use abbreviations only where specified. Place the following information, either hand-printed or in label form, on the metal can (or 1-gallon bottle):
 - Laboratory name and address.

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- Proper shipping name from the hazardous materials table (DOT Regulation CFR 49 172.101). Example: "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325." This will include packing group (see Section 5.3.4.2, No. 2.)

Not otherwise specified (n.o.s) is not used if the flammable liquid (or solid) is identified. If identified, the name of the specific material is listed before the category (for example, Acetone, Flammable Liquid), followed by its appropriate UN number found in the DOT Hazardous Materials table (49 CFR 172.101).

2. Determine packing group. The packing group is part of the proper shipping name and must be included on the shipping papers in the description section.

- I. Most Hazardous
- II. Medium Hazard
- III. Least Hazardous

The packing group will be listed in the hazardous materials table, column 5.

3. Place all information on outside shipping container as on can (or bottle), specifically:

- Proper shipping name
- UN or NA number
- Proper label(s)
- Addressee and sender

Place the following labels on the outside shipping container: "Cargo Aircraft Only" and DOT label such as: "Flammable Liquid" (or "Flammable Solid"). "Dangerous When Wet" label shall be used if the Flammable Solid has not been exposed to a wet environment. "Laboratory Samples" and "THIS SIDE UP" or "THIS END UP" shall also be marked on the top of the outside container, and upward-pointing arrows shall be placed on all four sides of the container.

5.4.3.3 Shipping Papers

1. Use abbreviations only where specified. Complete the carrier-provided bill of lading and sign certification statement. Provide the following information in the order listed (one form may be used for more than one exterior container):

- Proper shipping name. (Example: "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325 Packing Group I, II, III").
- "Limited Quantity" (or "Ltd. Qty."). (See No. 3, below.)
- "Cargo Aircraft Only."
- Net weight (wt) or net volume (vol), just before or just after "Flammable Liquid, n.o.s." or "Flammable Solid, n.o.s.," by item, if more than one metal can is inside an exterior container.
- "Laboratory Samples" (if applicable).

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2. Include Chain-of-Custody Record, properly executed in outside container; use custody seals.

3. "Limited Quantity" means the maximum amount of a hazardous material for which there is a specific labeling or packaging exception (DOT CFR 49 171.8). This may mean that packages are exempted from labeling requirements. To determine if your sample meets the Limited Quantity Exception, refer to DOT Regulation CFR 49 Subpart C 173.50 through 173.156. First, determine the proper classification and shipping name for the material; then refer to the exception requirements for that particular class of material beginning with 173.50.

Example: "Flammable Liquid n.o.s. UN1993 Packing Group 1." The outer package can weigh no more than 66 pounds gross weight. The inner package or container can weigh no more than 0.1 gallon net capacity for each container.

To determine whether the material can be shipped as a "Limited Quantity," you must check the specific requirement for that class of material.

5.4.3.4 Transportation

1. The majority of unknown hazardous substance samples will be classified as flammable liquids. The samples will be transported by rented or common carrier truck, railroad, or express overnight package services. Do not transport samples on any passenger-carrying air transport system, even if the system has cargo-only aircraft. DOT regulations permit regular airline cargo-only aircraft, but difficulties with most suggest avoiding them. Instead, ship by airline carriers that carry only cargo. If unsure of what mode of transportation to use, consult the FOL or Project Manager.¹
2. For transport by government-owned vehicle, including aircraft, DOT regulations do not apply. However, procedures described above, with the exception of execution of the bill of lading with certification, shall still be followed.
3. Use the hazardous materials shipping check list (Attachment E) as a guidance to ensure that all sample-handling requirements are satisfied.
4. In some cases, various materials may react if they break during shipment. To determine if you are shipping such materials, refer to the DOT compatibility chart in Attachment F.

5.5 Shipment of Lithium Batteries

Monitoring well data are analyzed using either the Hermit SE 1000 or the Hermit SE 2000 environmental data logger. These instruments are powered by lithium batteries. The Department of Transportation has determined that lithium batteries are a hazardous material and are to be shipped using the following information:

¹ Note: If you are unsure as how to ship the sample (hazardous or environmental sample), contact the FOL or Project Manager so that a decision can be made as to the proper shipping practices. The DOT penalties for improper shipment of a hazardous material are stringent and may include a prison term for intentional violations.

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- Product Designation
 - Hermit SE 1000
 - Hermit SE 2000
- DOT Proper Shipping Name
 - Lithium batteries, contained in equipment, UN3091
- Classification or Division
 - Class 9

Shipment of equipment containing lithium batteries must be accompanied by shipping papers completed as indicated in Attachment G. The instrument will be shipped by Federal Express as a Hazardous Material. Place the instrument in the same container in which it was received. This container or case is a DOT-approved shipping container. For Federal Express procedures to ship hazardous materials, call 1-800-238-5355, extension 922-1666. In most cases, the return shipping papers and DOT labels will be shipped to you from the company warehouse or the vendor. An example of the types of labels used for shipment and the wording are shown in Attachment G. These labels will be attached to the outside container with the following wording:

- Lithium Batteries Contained in Equipment
 - UN-3091
 - Shipped Under CA-9206009

6.0 REFERENCES

American Public Health Association, 1981. Standard Methods for the Examination of Water and Wastewater, 15th Edition. APHA, Washington, D.C.

U.S. Department of Transportation, 1993. Hazardous Materials Regulations, 49 CFR 171-177.

U.S. EPA, 1984. "Guidelines Establishing Test Procedures for the Analysis of Pollutants under Clean Water Act." Federal Register, Volume 49 (209), October 26, 1984, p. 43234.

U.S. EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020, U.S. EPA-EMSL, Cincinnati, Ohio.

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SAMPLE HANDLING

ATTACHMENT A

GENERAL SAMPLE CONTAINER AND PRESERVATION REQUIREMENTS

Sample Type and Concentration	Container ⁽¹⁾	Sample Size	Preservation ⁽²⁾	Holding Time ⁽²⁾
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WATER

Organics (GC&GC/MS)	VOC	Low	Borosilicate glass	2 x 40 mL	Cool to 4°C HCl to ≤ 2	14 days ⁽⁸⁾
	Extractables SVOCs and pesticide/PCBs)	(Low	Amber glass	2x2 L or 4x1 L	Cool to 4°C	7 days to extraction; 40 days after extraction
	Extractables SVOCs and pesticide/PCBs)	(Medium	Amber glass	2x2 L or 4x1 L	None	7 days to extraction; 40 days after extraction
Inorganics	Metals	Low	High-density polyethylene	1 L	HNO ₃ to pH ≤ 2	6 months (Hg-28 days)
		Medium	Wide-mouth glass	16 oz.	None	6 months
	Cyanide	Low	High-density polyethylene	1 L	NaOH to pH > 12	14 days
	Cyanide	Medium	Wide-mouth glass	16 oz.	None	14 days
Organic/ Inorganic	High Hazard		Wide-mouth glass	8 oz.	None	14 days

SOIL

Organics (GC&GC/MS)	VOC		Wide-mouth glass with teflon liner	2 x 4 oz.	Cool to 4°C	14 days
	Extractables SVOCs and pesticides/PCBs)	(Low	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
	Extractables SVOCs and pesticides/PCBs)	(Medium	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
Inorganics	Low/Medium		Wide-mouth glass	8 oz.	Cool to 4°C	6 months (Hg - 28 days) Cyanide (14 days)
Organic/ Inorganic	High Hazard		Wide-mouth glass	8 oz.	None	NA
Dioxin/Furan	All		Wide-mouth glass	4 oz.	None	7 days until extraction; 40 days after extraction
TCLP	All		Wide-mouth glass	8 oz.	None	7 days until preparation; analysis as per fraction

AIR

Volatile Organics	Low/Medium	Charcoal tube – 7 cm long, 6 mm OD, 4 mm ID	100 L air	Cool to 4°C	5 days recommended
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(1) All glass containers should have Teflon cap liners or septa.

(2) See Attachment E. Preservation and maximum holding time allowances per 40 CFR 136.

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ATTACHMENT B

ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter Number/Name	Container ⁽¹⁾	Preservation ⁽²⁾⁽³⁾	Maximum Holding Time ⁽⁴⁾
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INORGANIC TESTS:

Acidity	P, G	Cool, 4°C	14 days
Alkalinity	P, G	Cool, 4°C	14 days
Ammonia - Nitrogen	P, G	Cool, 4°C; H ₂ SO ₄ to pH 2	28 days
Biochemical Oxygen Demand (BOD)	P, G	Cool, 4°C	48 hours
Bromide	P, G	None required	28 days
Chemical Oxygen Demand (COD)	P, G	Cool, 4°C; H ₂ SO ₄ to pH 2	28 days
Chloride	P, G	None required	28 days
Chlorine, Total Residual	P, G	None required	Analyze immediately
Color	P, G	Cool, 4°C	48 hours
Cyanide, Total and Amenable to Chlorination	P, G	Cool, 4°C; NaOH to pH 12; 0.6 g ascorbic acid ⁽⁵⁾	14 days ⁽⁶⁾
Fluoride	P	None required	28 days
Hardness	P, G	HNO ₃ to pH 2; H ₂ SO ₄ to pH 2	6 months
Total Kjeldahl and Organic Nitrogen	P, G	Cool, 4°C; H ₂ SO ₄ to pH 2	28 days
Nitrate - Nitrogen	P, G	None required	48 hours
Nitrate-Nitrite - Nitrogen	P, G	Cool, 4°C; H ₂ SO ₄ to pH 2	28 days
Nitrite - Nitrogen	P, G	Cool, 4°C	48 hours
Oil & Grease	G	Cool, 4°C; H ₂ SO ₄ to pH 2	28 days
Total Organic Carbon (TOC)	P, G	Cool, 4°C; HCl or H ₂ SO ₄ to pH 2	28 days
Orthophosphate	P, G	Filter immediately; Cool, 4°C	48 hours
Oxygen, Dissolved-Probe	G Bottle & top	None required	Analyze immediately
Oxygen, Dissolved-Winkler	G Bottle & top	Fix on site and store in dark	8 hours
Phenols	G	Cool, 4°C; H ₂ SO ₄ to pH 2	28 days
Phosphorus, Total	P, G	Cool, 4°C; H ₂ SO ₄ to pH 2	28 days
Residue, Total	P, G	Cool, 4°C	7 days
Residue, Filterable (TDS)	P, G	Cool, 4°C	7 days
Residue, Nonfilterable (TSS)	P, G	Cool, 4°C	7 days
Residue, Settleable	P, G	Cool, 4°C	48 hours
Residue, Volatile (Ash Content)	P, G	Cool, 4°C	7 days
Silica	P	Cool, 4°C	28 days
Specific Conductance	P, G	Cool, 4°C	28 days
Sulfate	P, G	Cool, 4°C	28 days

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ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES,
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Parameter Number/Name	Container ⁽¹⁾	Preservation ⁽²⁾⁽³⁾	Maximum Holding Time ⁽⁴⁾
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INORGANIC TESTS (Cont'd):

Sulfide	P, G	Cool, 4°C; add zinc acetate plus sodium hydroxide to pH 9	7 days
Sulfite	P, G	None required	Analyze immediately
Turbidity	P, G	Cool, 4°C	48 hours

METALS:⁽⁷⁾

Chromium VI (Hexachrome)	P, G	Cool, 4°C	24 hours
Mercury (Hg)	P, G	HNO ₃ to pH 2	28 days
Metals, except Chromium VI and Mercury	P, G	HNO ₃ to pH 2	6 months

ORGANIC TESTS:⁽⁸⁾

Purgeable Halocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	14 days
Purgeable Aromatic Hydrocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾ HCl to pH 2 ⁽⁸⁾	14 days
Acrolein and Acrylonitrile	G, Teflon-lined septum	Cool, 4°C; 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾ adjust pH to 4-5 ⁽¹⁰⁾	14 days
Phenols ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C; 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	7 days until extraction; 40 days after extraction
Benzidines ^{(11), (12)}	G, Teflon-lined cap	Cool, 4°C; 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	7 days until extraction ⁽¹³⁾
Phthalate esters ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitrosamines ^{(11), (14)}	G, Teflon-lined cap	Cool, 4°C; store in dark; 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	7 days until extraction; 40 days after extraction
PCBs ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitroaromatics & Isophorone ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C; 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾ ; store in dark	7 days until extraction; 40 days after extraction
Polynuclear Aromatic Hydrocarbons (PAHs) ^{(11),(14)}	G, Teflon-lined cap	Cool, 4°C; 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾ ; store in dark	7 days until extraction; 40 days after extraction
Haloethers ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C; 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	7 days until extraction; 40 days after extraction
Dioxin/Furan (TCDD/TCDF) ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C; 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	7 days until extraction; 40 days after extraction

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**ATTACHMENT B
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES,
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Parameter Number/Name	Container ⁽¹⁾	Preservation ⁽²⁾⁽³⁾	Maximum Holding Time ⁽⁴⁾
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RADIOLOGICAL TESTS:

1-5 Alpha, beta and radium	P, G	HNO ₃ to pH 2	6 months
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- (1) Polyethylene (P): generally 500 ml or Glass (G): generally 1L.
- (2) Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.
- (3) When any sample is to be shipped by common carrier or sent through the United States Mail, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172).
- (4) Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of samples under study are stable for the longer periods, and has received a variance from the Regional Administrator.
- (5) Should only be used in the presence of residual chlorine.
- (6) Maximum holding time is 24 hours when sulfide is present. Optionally, all samples may be tested with lead acetate paper before pH adjustments are made to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.
- (7) Samples should be filtered immediately on site before adding preservative for dissolved metals.
- (8) Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.
- (9) Sample receiving no pH adjustment must be analyzed within 7 days of sampling.
- (10) The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.
- (11) When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6-9; samples preserved in this manner may be held for 7 days before extraction and for 40 days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re: the requirement for thiosulfate reduction of residual chlorine) and footnotes 12, 13 (re: the analysis of benzidine).
- (12) If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0±0.2 to prevent rearrangement to benzidine.
- (13) Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.
- (14) For the analysis of diphenylnitrosamine, add 0.008% Na₂S₂O₃ and adjust pH to 7-10 with NaOH within 24 hours of sampling.
- (15) The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% Na₂S₂O₃.

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ATTACHMENT C

DOT HAZARDOUS MATERIAL CLASSIFICATION (49 CFR 173.2a)

1. Radioactive material (except a limited quantity)
2. Division 2.3, Poisonous Gases
3. Division 2.1, Flammable Gas
4. Division 2.2, Nonflammable gas
5. Division 6.1, Poisonous Liquids, Packing Group 1 (poison by inhalation only)
6. Division 4.2, Pyrophoric Material
7. Division 4.1, Self-Reactive Material
8. Class 3, Flammable Liquids*
9. Class 8, Corrosive Material
10. Division 4.1, Flammable Solid*
11. Division 4.2, Spontaneously Combustible Materials*
12. Division 4.3, Dangerous When Wet Materials*
13. Division 5.1, Oxidizers*
14. Division 6.1, Poisonous Liquids or Solids (other than Packing Group 1)*
15. Combustible liquid
16. Class 9, Miscellaneous Hazardous Materials

* If a material has or meets the criteria for more than one hazard class, use the precedence of hazardous table on the following page for Classes 3 and 8 and Divisions 4.1, 4.2, 4.3, 5.1, and 6.1. The following table ranks those materials that meet the definition of Classes 3 and 8 and Divisions 4.1, 4.2, 4.3, 5.1, and 6.1.

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ATTACHMENT C (Continued)

PRECEDENCE OF HAZARD TABLE

(Hazard Class and Packing Group)

Class	Packing Group	4.2	4.3	5.1 I ^(a)	5.1 II ^(b)	5.1 III ^(c)	6.1 I (Dermal)	6.1 I (Oral)	6.1 II	6.1 III	8 I (Liquid)	8 I (Solid)	8 II (Liquid)	8 II (Solid)	8 III (Liquid)	8 III (Solid)
3	I						3	3	3	3	3	(d)	3	(d)	3	(d)
3	II						3	3	3	3	8	(d)	3	(d)	3	(d)
3	III						6.1	6.1	6.1	3 ^(d)	8	(d)	8	(d)	3	(d)
4.1	II ^b	4.2	4.3	5.1	4.1	4.1	6.1	6.1	4.1	4.1	(d)	8	(d)	4.1	(d)	4.1
4.1	III ^b	4.2	4.3	5.1	4.1	4.1	6.1	6.1	6.1	4.1	(d)	8	(d)	8	(d)	4.1
4.2	II		4.3	5.1	4.2	4.2	6.1	6.1	4.2	4.2	(d)	8	(d)	4.2	(d)	4.2
4.2	III		4.3	5.1	4.2	4.2	6.1	6.1	6.1	4.2	(d)	8	(d)	8	(d)	4.2
4.3	I			5.1	4.3	4.3	6.1	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
4.3	II			5.1	4.3	4.3	6.1	4.3	4.3	4.3	8	8	8	4.3	4.3	4.3
4.3	III			5.1	4.3	4.3	6.1	6.1	6.1	4.3	8	8	8	4.3	4.3	4.3
5.1	I ^a						5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
5.1	II ^a						6.1	5.1	5.1	5.1	8	8	8	5.1	5.1	5.1
5.1	III ^a						6.1	6.1	6.1	5.1	8	8	8	5.1	5.1	5.1
6.1	I, Dermal										8	6.1	6.1	6.1	6.1	6.1
6.1	I, Oral										8	6.1	6.1	6.1	6.1	6.1
6.1	II, Inhalation										8	6.1	6.1	6.1	6.1	6.1
6.1	II, Dermal										8	6.1	8	6.1	6.1	6.1
6.1	II, Oral										8	8	8	6.1	6.1	6.1
6.1	III										8	8	8	8	8	8

(a) There are at present no established criteria for determining Packing Groups for liquids in Division 5.1. At present, the degree of hazard is to be assessed by analogy with listed substances, allocating the substances to Packing Group I, Great; Group II, Medium; or Group III, Minor Danger.

(b) Substances of Division 4.1 other than self-reactive substances.

(c) Denotes an impossible combination.

(d) For pesticides only, where a material has the hazards of Class 3, Packing Group III, and Division 6.1, Packing Group III, the primary hazard is Division 6.1, Packing Group III.

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ATTACHMENT D

GUIDE FOR HAZARDOUS MATERIALS SHIPPERS

USE OF GUIDE - This guide is presented as an aid to shippers of hazardous materials. It does not contain or refer to all of the DOT requirements for shipping hazardous materials. For specific details, refer to all of the DOT requirements for shipping hazardous materials, as provided in the Code of Federal Regulations (CFR), Title 49, Transportation, Parts 100-199.

The following is offered as a step-by-step procedure to aid in compliance with the applicable DOT regulations.

STEP 1 - DETERMINE THE PROPER SHIPPING NAME. The shipper must determine the proper shipping name of the materials as listed in the Hazardous Materials Table, 49 CFR 172.101, Column (2).

STEP 2 - DETERMINE THE HAZARD CLASS OR CLASSES.

- a. Refer to the Table, 49 CFR 172.101, Column (3), and locate the hazard class of the material.
- b. If more than one class is shown for the proper shipping name, determine the proper class by definition.
- c. If the materials have more than one hazard, classify the material based on the order of hazards in 49 CFR 173.2.

STEP 3 - SELECT THE PROPER IDENTIFICATION NUMBERS.

- a. Refer to the Table, 49 CFR 172.101, Column (3a), and select the Identification Number (ID) that corresponds to the proper shipping name and hazard class.
- b. Enter the ID number(s) on the shipping papers and display them, as required, on packagings, placards and/or orange panels.

STEP 4 - DETERMINE THE MODE(S) OF TRANSPORT TO ULTIMATE DESTINATION.

- a. As a shipper, you must assure yourself that the shipment complies with various modal requirements.
- b. The modal requirements may affect the following: (1) Packaging; (2) Quantity per Package; (3) Marking; (4) Labeling; (5) Shipping Papers; and (6) Certification.

STEP 5 - SELECT THE PROPER LABEL(S) AND APPLY AS REQUIRED.

- a. Refer to the Table, 49 CFR 172.101, Column (4) for required labels.
- b. For details on labeling refer to (1) Additional Labels, 49 CFR 172.402; (2) Placement of Labels, 49 CFR 172.406; (3) Packagings (Mixed or Consolidated), 49 CFR 172.404(a) and (h); (4) Packages Containing Samples, 49 CFR 172.402(h); (5) Radioactive Materials, 49 CFR 172.403; and (6) Authorized Label Modifications, 49 CFR 172.405.

STEP 6 - DETERMINE AND SELECT THE PROPER PACKAGES.

- a. Refer to the Table, 49 CFR 172.101, Column (5a) for exceptions and Column (5b) for specification packagings. Consider the following when selecting an authorized package: Quantity per Package; Cushioning Material, if required; Proper Closure and Reinforcement; Proper Pressure; Outage; etc., as required.
- b. If packaged by a prior shipper, make sure the packaging is correct and in proper condition for transportation.

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ATTACHMENT D (Continued)
GUIDE FOR HAZARDOUS MATERIALS SHIPPERS

STEP 7 - MARK THE PACKAGING (INCLUDING OVERPACKS).

- a. Apply the required markings (49 CFR 172.300); Proper shipping name and ID number, when required (49 CFR 172.301); Name and address of Consignee or Consignor (49 CFR 172.306).
- b. For details and other required markings, see 49 CFR 172.300 through 172.338.

STEP 8 - PREPARE THE SHIPPING PAPERS.

- a. The basic requirements for preparing shipping papers include Proper Shipping Name; Hazard Class; ID Number; Total Quantity; Shipper's Certification; and Emergency Response Telephone Number.
- b. Make all entries on the shipping papers using the information required and in proper sequence (49 CFR 172.202).

STEP 9 - CERTIFICATION.

- a. Each shipper must certify by printing (manually or mechanically) on the shipping papers that the materials being offered for shipment are properly classified, described, packaged, marked and labeled, and in proper condition for transportation according to the applicable DOT Regulations (49 CFR 172.202).

STEP 10 - LOADING, BLOCKING, AND BRACING. When hazardous materials are loaded into the transport vehicle or freight container, each package must be loaded, blocked, and braced in accordance with the requirements for mode of transport.

- a. If the shipper loads the freight container or transport vehicle, the shipper is responsible for the proper loading, blocking, and bracing of the materials.
- b. If the carrier does the loading, the carrier is responsible.

STEP 11 - DETERMINE THE PROPER PLACARD(S). Each person who offers hazardous materials for transportation must determine that the placarding requirements have been met.

- a. For Highway, unless the vehicle is already correctly placarded, the shipper must provide the required placard(s) and required ID number(s) (49 CFR 172.506).
- b. For Rail, if loaded by the shipper, the shipper must placard the rail car if placards are required (49 CFR 172.508).
- c. For Air and Water shipments, the shipper has the responsibility to apply the proper placards.

STEP 12 - HAZARDOUS WASTE/HAZARDOUS SUBSTANCE.

- a. If the material is classed as a hazardous waste or hazardous substance, most of the above steps will be applicable.
- b. Pertinent Environmental Protection Agency regulations are found in the Code of Federal Regulations, Title 40, Part 262.

As a final check and before offering the shipment for transportation, visually inspect your shipment. The shipper should ensure that emergency response information is on the vehicle for transportation of hazardous materials.

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Revised March 1995.

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ATTACHMENT E

HAZARDOUS MATERIALS SHIPPING CHECK LIST

PACKAGING

1. Check DOT 173.24 for appropriate type of package for hazardous substance.
2. Check for container integrity, especially the closure.
3. Check for sufficient absorbent material in package.
4. Check for sample tags and log sheets for each sample and for chain-of-custody record.

SHIPPING PAPERS

1. Check that entries contain only approved DOT abbreviations.
2. Check that entries are in English.
3. Check that hazardous material entries are specially marked to differentiate them from any nonhazardous materials being sent using same shipping paper.
4. Be careful that all hazardous classes are shown for multiclass materials.
5. Check total amounts by weight, quantity, or other measures used.
6. Check that any limited-quantity exemptions are so designated on the shipping paper.
7. Check that certification is signed by shipper.
8. Make certain driver signs for shipment.

RCRA MANIFEST

1. Check that approved state/federal manifests are prepared.
2. Check that transporter has the following: valid EPA identification number, valid driver's license, valid vehicle registration, insurance protection, and proper DOT labels for materials being shipped.
3. Check that destination address is correct.
4. Check that driver knows where shipment is going.
5. Check that the driver is aware of emergency procedures for spills and accidents.
6. Make certain driver signs for shipment.
7. Make certain one copy of executed manifest and shipping document is retained by shipper.

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ATTACHMENT F
DOT SEGREGATION AND SEPARATION CHART

Class or Division	Notes	1.1-1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3 gas Zone A*	2.3 gas Zone B*	3	4.1	4.2	4.3	5.1	5.2	6.1 liquids PG-I Zone A*	7	8 liquids only
Explosives 1.1 and 1.2	A	*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Explosives 1.3		*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Explosives 1.4		*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Very insensitive explosives 1.5	A	*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Extremely insensitive explosives 1.6		*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Flammable gases 2.1		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Non-toxic, non-flammable gases 2.2		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Poisonous gas - Zone A** 2.3		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Poisonous gas - Zone B** 2.3		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Flammable liquids 3		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Flammable solids 4.1		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spontaneously combustible materials 4.2		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dangerous-when-wet materials 4.3		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Oxidizers 5.1	A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Organic peroxides 5.2		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Poisonous liquids PG I - Zone A** 6.1		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Radioactive materials 7		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Corrosive liquids 8		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

No entry means that the materials are compatible (have no restrictions).

X These materials may not be loaded, transported, or stored together in the same vehicle or facility.

O The materials may not be loaded, transported, or stored together in the same vehicle or facility unless they are separated for 4 feet on all sides.

* Check the explosives compatibility chart in 49 CFR 179.848(f).

A Ammonium nitrate fertilizers may be stored with Division 1.1 materials.

** Denotes inhalation hazardous for poisons; consult field team leader or project manager if you encounter a material in this class before shipment.

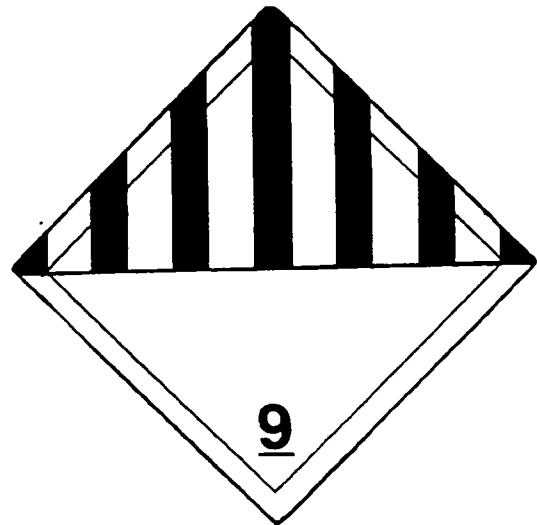
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**ATTACHMENT G
LITHIUM BATTERY SHIPPING PAPERS**

3224637861		Two completed and signed copies of this Declaration must be handed to the operator. WARNING Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.	
TRANSPORT DETAILS This shipment is within the limitations prescribed for: (delete non-applicable) <input checked="" type="checkbox"/> PASSENGER AIRCRAFT <input type="checkbox"/> CARGO AIRCRAFT ONLY		Airport of Departure Airport of Destination: 19CYS	
Shipment type: (delete non-applicable) <input checked="" type="checkbox"/> NON-RADIOACTIVE <input type="checkbox"/> RADIOACTIVE			
NATURE AND QUANTITY OF DANGEROUS GOODS Dangerous Goods Identification			
Proper Shipping Name LITHIUM BATTERIES CONTAINED IN EQUIPMENT	Class or Division 9	UN or ID No. UN3091	Quantity and type of packing 1 PLASTIC BOX X 55 GRAMS
			Packing Inat. 912 II
			Authorization PER CA-9206009
Additional Handling Information 1 HERMIT SERIES DATALOGGER X 55 GRAMS (11 GRAMS/CELL)			
I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked, and labeled, and are in all respects in the proper condition for transport by air according to the applicable International and National Government Regulations.			
Emergency Telephone Number (Required for US Origin or Destination Shipments) 800-535-5053		Name/Title of Signatory Place and Date Signature (see warning above)	
IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.			

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ATTACHMENT G (CONTINUED)
LITHIUM BATTERY SHIPPING PAPERS



**LITHIUM BATTERIES CONTAINED
IN EQUIPMENT.
UN-3091.
SHIPPED UNDER CA-9206009**



BROWN & ROOT ENVIRONMENTAL

STANDARD OPERATING PROCEDURES

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Revision
0

Applicability
B&R Environmental, NE

Prepared
Earth Sciences Department

Subject FIELD DOCUMENTATION

Approved
D. Senovich

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to identify and designate the field data record forms, logs and reports generally initiated and maintained for documenting Brown & Root Environmental field activities.

2.0 SCOPE

Documents presented within this procedure (or equivalents) shall be used for all Brown & Root Environmental field activities, as applicable. Other or additional documents may be required by specific client contracts.

3.0 GLOSSARY

None

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for obtaining hardbound, controlled-distribution logbooks (from the appropriate source), as needed. In addition, the Project Manager is responsible for placing all forms used in site activities (i.e., records, field reports, and upon the completion of field work, the site logbook) in the project's central file.

Field Operations Leader (FOL) - The Field Operations Leader is responsible for ensuring that the site logbook, notebooks, and all appropriate forms and field reports illustrated in this guideline (and any additional forms required by the contract) are correctly used, accurately filled out, and completed in the required time-frame.

5.0 PROCEDURES

5.1 Site Logbook

5.1.1 General

The site logbook is a hard-bound, paginated controlled-distribution record book in which all major onsite activities are documented. At a minimum, the following activities/events shall be recorded (daily) in the site logbook:

- All field personnel present
- Arrival/departure of site visitors
- Arrival/departure of equipment
- Start or completion of borehole/trench/monitoring well installation or sampling activities
- Daily onsite activities performed each day
- Sample pickup information
- Health and Safety issues (level of protection observed, etc.)
- Weather conditions

A site logbook shall be maintained for each project. The site logbook shall be initiated at the start of the first onsite activity (e.g., site visit or initial reconnaissance survey). Entries are to be made for every day that onsite activities take place which involve Brown & Root Environmental or subcontractor personnel. Upon completion of the fieldwork, the site logbook must become part of the project's central file.

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The following information must be recorded on the cover of each site logbook:

- Project name
- Brown & Root Environmental project number
- Sequential book number
- Start date
- End date

Information recorded daily in the site logbook need not be duplicated in other field notebooks (see Section 5.2), but must summarize the contents of these other notebooks and refer to specific page locations in these notebooks for detailed information (where applicable). An example of a typical site logbook entry is shown in Attachment A.

If measurements are made at any location, the measurements and equipment used must either be recorded in the site logbook or reference must be made to the site notebook in which the measurements are recorded (see Attachment A).

All logbook, notebook, and log sheet entries shall be made in indelible ink (black pen is preferred). No erasures are permitted. If an incorrect entry is made, the data shall be crossed out with a single strike mark, and initialed and dated. At the completion of entries by any individual, the logbook pages used must be signed and dated. The site logbook must also be signed by the Field Operations Leader at the end of each day.

5.1.2 Photographs

When movies, slides, or photographs are taken of a site or any monitoring location, they must be numbered sequentially to correspond to logbook entries. The name of the photographer, date, time, site location, site description, and weather conditions must be entered in the logbook as the photographs are taken. A series entry may be used for rapid-sequence photographs. The photographer is not required to record the aperture settings and shutter speeds for photographs taken within the normal automatic exposure range. However, special lenses, films, filters, and other image-enhancement techniques must be noted in the logbook. If possible, such techniques shall be avoided, since they can adversely affect the admissibility of photographs as evidence. Chain-of-custody procedures depend upon the subject matter, type of film, and the processing it requires. Film used for aerial photography, confidential information, or criminal investigation require chain-of-custody procedures. Adequate logbook notation and receipts must be compiled to account for routine film processing. Once processed, the slides of photographic prints shall be consecutively numbered and labeled according to the logbook descriptions. The site photographs and associated negatives must be docketed into the project's central file.

5.2 Site Notebooks

Key field team personnel may maintain a separate dedicated notebook to document the pertinent field activities conducted directly under their supervision. For example, on large projects with multiple investigative sites and varying operating conditions, the Health and Safety Officer may elect to maintain a separate site notebook. Where several drill rigs are in operation simultaneously, each site geologist assigned to oversee a rig must maintain a site notebook.

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5.3 Sample Forms

A summary of the forms illustrated in this procedure is shown as the listing of Attachments in the Table of Contents for this SOP. Forms may be altered or revised for project-specific needs contingent upon client approval. Care must be taken to ensure that all essential information can be documented. Guidelines for completing these forms can be found in the related sampling SOP.

5.3.1 Sample Collection, Labeling, Shipment and Request for Analysis

5.3.1.1 Sample Log Sheet

Sample Log Sheets are used to record specified types of data while sampling. Attachments B-1 to B-4 are examples of Sample Log Sheets. The data recorded on these sheets are useful in describing the waste source and sample as well as pointing out any problems encountered during sampling. A log sheet must be completed for each sample obtained, including field quality control (QC) samples.

5.3.1.2 Sample Label

A typical sample label is illustrated in Attachment B-5. Adhesive labels must be completed and applied to every sample container. Sample labels can usually be obtained from the appropriate Program source or are supplied from the laboratory subcontractor.

5.3.1.3 Chain-of-Custody Record Form

The Chain-of-Custody (COC) Record is a multi-part form that is initiated as samples are acquired and accompanies a sample (or group of samples) as they are transferred from person to person. This form must be used for any samples collected for chemical or geotechnical analysis whether the analyses are performed on site or off site. One part of the completed COC form is retained by the field crew while the other two or three portions are sent to the laboratory. The original (top, signed copy) and extra carbonless copies of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the first cooler. The COC form should then state how many coolers are included with that shipment. An example of a Chain-of-Custody Record form is provided as Attachment B-6. A supply of these forms are purchased and stocked by the field department of the various Brown & Root Environmental offices. Alternately, COC forms supplied by the laboratory may be used. Once the samples are received at the laboratory, the sample cooler and contents are checked and any problems are noted on the enclosed COC form (any discrepancies between the sample labels and COC form and any other problems that are noted are resolved through communication between the laboratory point-of-contact and the Brown & Root Environmental Project Manager). The COC form is signed and one of the remaining two parts are retained by the laboratory while the last part becomes part of the samples' corresponding analytical data package. Internal laboratory chain-of-custody procedures are documented in the Laboratory Quality Assurance Plan (LQAP).

5.3.1.4 Chain-of-Custody Seal

Attachment B-7 is an example of a custody seal. The Custody seal is also an adhesive-backed label. It is part of a chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field and sealed in coolers for transit to the laboratory. The COC seals are signed and dated by the samplers and affixed across the opening edges of each cooler containing environmental samples. COC seals may be available from the laboratory; these seals may also be purchased from a supplier.

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5.3.2 Geohydrological and Geotechnical Forms

5.3.2.1 Groundwater Level Measurement Sheet

A groundwater level measurement sheet, shown in Attachment C-1 must be filled out for each round of water level measurements made at a site.

5.3.2.2 Data Sheet for Pumping Test

During the performance of a pumping test (or an in-situ hydraulic conductivity test), a large amount of data must be recorded, often within a short time period. The pumping test data sheet (Attachment C-2) facilitates this task by standardizing the data collection format, and allowing the time interval for collection to be laid out in advance.

5.3.2.3 Packer Test Report Form

A packer test report form shown in Attachment C-3 must be completed for each well upon which a packer test is conducted following well installation.

5.3.2.4 Summary Log of Boring

During the progress of each boring, a log of the materials encountered, operation and driving of casing, and location of samples must be kept. The Summary Log of Boring (Attachment C-4) is used for this purpose and must be completed for each soil boring performed. In addition, if volatile organics are monitored on cores, samples or cuttings from the borehole (using HNU or OVA detectors), these results must be entered on the boring log (under the "Remarks" column) at the appropriate depth. The "Remarks" column can also be used to subsequently enter the laboratory sample number and the concentration of a few key analytical results. This feature allows direct comparison of contaminant concentrations with soil characteristics.

5.3.2.5 Monitoring Well Construction Details Form

A Monitoring Well Construction Details Form must be completed for every monitoring well piezometer or temporary well point installed. This form contains specific information on length and type of well riser pipe and screen, backfill, filter pack, annular seal and grout characteristics, and surface seal characteristics. This information is important in evaluating the performance of the monitoring well, particularly in areas where water levels show temporal variation, or where there are multiple (immiscible) phases of contaminants. Depending on the type of monitoring well (in overburden or bedrock), different forms are used (see Attachments C-5 through C-9). Similar forms are used for flush-mount well completions. The Monitoring Well Construction Details Form is not a controlled document.

5.3.2.6 Test Pit Log

When a test pit or trench is constructed for investigative or sampling purposes, a Test Pit Log (Attachment C-10) must be filled out by the responsible field geologist or sampling technician.

5.3.3 Equipment Calibration and Maintenance Form

The calibration or standardization of monitoring, measuring or test equipment is necessary to assure the proper operation and response of the equipment, to document the accuracy, precision or sensitivity of the measurement, and determine if correction should be applied to the readings. Some items of

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equipment require frequent calibration, others infrequent. Some are calibrated by the manufacturer, others by the user.

Each instrument requiring calibration has its own Equipment Calibration Log (Attachment D) which documents that the manufacturer's instructions were followed for calibration of the equipment, including frequency and type of standard or calibration device. An Equipment Calibration Log must be maintained for each electronic measuring device used in the field; entries must be made for each day the equipment is used.

5.4 Field Reports

The primary means of recording onsite activities is the site logbook. Other field notebooks may also be maintained. These logbooks and notebooks (and supporting forms) contain detailed information required for data interpretation or documentation, but are not easily useful for tracking and reporting of progress. Furthermore, the field logbook/notebooks remain onsite for extended periods of time and are thus not accessible for timely review by project management.

5.4.1 Weekly Status Reports

To facilitate timely review by project management, Xeroxed copies of logbook/notebook entries may be made for internal use. To provide timely oversight of onsite contractors, Daily Activities Reports are completed and submitted as described below.

It should be noted that in addition to the summaries described herein, other summary reports may also be contractually required.

5.4.2 Daily Activities Report

5.4.2.1 Description

The Daily Activities Report (DAR) documents the activities and progress for each day's field work. This report must be filled out on a daily basis whenever there are drilling, test pitting, well construction, or other related activities occurring which involve subcontractor personnel. These sheets summarize the work performed and form the basis of payment to subcontractors (Attachment E is an example of a Daily Activities Report).

5.4.2.2 Responsibilities

It is the responsibility of the rig geologist to complete the DAR and obtain the driller's signature acknowledging that the times and quantities of material entered are correct.

5.4.2.3 Submittal and Approval

At the end of the shift, the rig geologist must submit the Daily Activities Report to the Field Operations Leader (FOL) for review and filing. The Daily Activities Report is not a formal report and thus requires no further approval. The DAR reports are retained by the FOL for use in preparing the site logbook and in preparing weekly status reports for submission to the Project Manager.

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6.0 ATTACHMENTS

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Attachment C-9	EXAMPLE TEST PIT LOG
Attachment D	EXAMPLE EQUIPMENT CALIBRATION LOG
Attachment E	EXAMPLE DAILY ACTIVITIES RECORD
Attachment F	FIELD TRIP SUMMARY REPORT

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**ATTACHMENT A
TYPICAL SITE LOGBOOK ENTRY**

START TIME: _____ DATE: _____

SITE LEADER: _____

PERSONNEL: -

BROWN & ROOT ENV.

DRILLER

EPA

WEATHER: Clear, 68°F, 2-5 mph wind from SE


ACTIVITIES:

1. Steam jenny and fire hoses were set up.
2. Drilling activities at well _____ resumes. Rig geologist was _____. See Geologist's Notebook, No. 1, page 29-30, for details of drilling activity. Sample No. 123-21-S4 collected; see sample logbook, page 42. Drilling activities completed at 11:50 and a 4-inch stainless steel well installed. See Geologist's Notebook, No. 1, page 31, and well construction details for well _____.
3. Drilling rig No. 2 steam-cleaned at decontamination pit. Then set up at location of well _____.
4. Well _____ drilled. Rig geologist was _____. See Geologist's Notebook, No. 2, page _____ for details of drilling activities. Sample numbers 123-22-S1, 123-22-S2, and 123-22-S3 collected; see sample logbook, pages 43, 44, and 45.
5. Well _____ was developed. Seven 55-gallon drums were filled in the flushing stage. The well was then pumped using the pitcher pump for 1 hour. At the end of the hour, water pumped from well was "sand free."
6. EPA remedial project manger arrives on site at 14:25 hours.
7. Large dump truck arrives at 14:45 and is steam-cleaned. Backhoe and dump truck set up over test pit _____.
8. Test pit _____ dug with cuttings placed in dump truck. Rig geologist was _____. See Geologist's Notebook, No. 1, page 32, for details of test pit activities. Test pit subsequently filled. No samples taken for chemical analysis. Due to shallow groundwater table, filling in of test pit _____ resulted in a very soft and wet area. A mound was developed and the area roped off.
9. Express carrier picked up samples (see Sample Logbook, pages 42 through 45) at 17:50 hours. Site activities terminated at 18:22 hours. All personnel off site, gate locked.

Field Operations Leader

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**ATTACHMENT B-1
EXAMPLE GROUNDWATER SAMPLE LOG SHEET**

		GROUNDWATER SAMPLE LOG SHEET		Page ____ of ____																																																																																																																															
Project Site Name: _____		Sample ID No.: _____																																																																																																																																	
Project No.: _____		Sample Location: _____																																																																																																																																	
<input type="checkbox"/> Domestic Well Data <input type="checkbox"/> Monitoring Well Data <input type="checkbox"/> Other Well Type: _____ <input type="checkbox"/> QA Sample Type: _____		Sampled By: _____ C.O.C. No.: _____																																																																																																																																	
<table border="1"> <thead> <tr> <th colspan="9">Sampling Data</th> </tr> <tr> <th>Date: _____</th> <th>pH</th> <th>S.C.</th> <th>Temp. (°C)</th> <th>Turbidity</th> <th>Color</th> <th>TBD</th> <th>TBD</th> <th>TBD</th> </tr> </thead> <tbody> <tr> <td>Time: _____</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Method: _____</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>						Sampling Data									Date: _____	pH	S.C.	Temp. (°C)	Turbidity	Color	TBD	TBD	TBD	Time: _____									Method: _____																																																																																																		
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**ATTACHMENT B-4
CONTAINER SAMPLE LOG SHEET FORM**



Brown & Root Environmental

Page ____ of ____

☐ Container Data

Case #: _____

By: _____

Project Site Name: _____ Project Site No. _____


Brown & Root Env. Source No. _____ Source Location: _____

Container Source	Container Description																										
<input type="checkbox"/> Drum <input type="checkbox"/> Bung Top <input type="checkbox"/> Lever Lock <input type="checkbox"/> Bolted Ring <input type="checkbox"/> Other _____ <input type="checkbox"/> Bag/Sack <input type="checkbox"/> Tank <input type="checkbox"/> Other _____	Color: _____ Condition: _____ Markings: _____ Vol. of Contents: _____ Other: _____																										
Disposition of Sample <input type="checkbox"/> Container Sampled <input type="checkbox"/> Container opened but not sampled. Reason: _____ <input type="checkbox"/> Container not opened. Reason: _____	Sample Description <table border="1"> <thead> <tr> <th></th> <th>Layer 1</th> <th>Layer 2</th> <th>Layer 3</th> </tr> <tr> <th>Phase</th> <td><input type="checkbox"/> Sol. <input type="checkbox"/> Liq.</td> <td><input type="checkbox"/> Sol. <input type="checkbox"/> Liq.</td> <td><input type="checkbox"/> Sol. <input type="checkbox"/> Liq.</td> </tr> <tr> <th>Color</th> <td>_____</td> <td>_____</td> <td>_____</td> </tr> <tr> <th>Viscosity</th> <td><input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H</td> <td><input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H</td> <td><input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H</td> </tr> <tr> <th>% of Total Volume</th> <td>_____</td> <td>_____</td> <td>_____</td> </tr> <tr> <th>Other</th> <td>_____</td> <td>_____</td> <td>_____</td> </tr> </thead></table>				Layer 1	Layer 2	Layer 3	Phase	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.	Color	_____	_____	_____	Viscosity	<input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H	<input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H	<input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H	% of Total Volume	_____	_____	_____	Other	_____	_____	_____
	Layer 1	Layer 2	Layer 3																								
Phase	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.																								
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% of Total Volume	_____	_____	_____																								
Other	_____	_____	_____																								
Monitor Reading:	Type of Sample <input type="checkbox"/> Low Concentration <input type="checkbox"/> High Concentration <input type="checkbox"/> Grab <input type="checkbox"/> Composite <input type="checkbox"/> Grab-composite																										
Sample Method:																											
Sample Date & Time:	Sample Identification	Organic	Inorganic																								
Sampled by:																											
Signature(s):																											
	Date Shipped																										
Analysis:	Time Shipped																										
	Lab																										
	Volume																										

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ATTACHMENT B-5

SAMPLE LABEL

 Brown & Root Environmental		PROJECT: _____	
STATION LOCATION: _____			
DATE: ____/____/____		TIME: _____ hrs.	
MEDIA: WATER <input type="checkbox"/>		SOIL <input type="checkbox"/>	SEDIMENT <input type="checkbox"/>
CONCENTRATION: LOW <input type="checkbox"/>		MEDIUM <input type="checkbox"/>	HIGH <input type="checkbox"/>
TYPE: GRAB <input type="checkbox"/>		COMPOSITE <input type="checkbox"/>	
ANALYSIS		PRESERVATION	
VOA <input type="checkbox"/>	BNAs <input type="checkbox"/>	Cool to 4°C	<input type="checkbox"/>
PCBs <input type="checkbox"/>	PESTICIDES <input type="checkbox"/>	HNO ₃ to pH < 2	<input type="checkbox"/>
METALS: TOTAL <input type="checkbox"/>	DISSOLVED <input type="checkbox"/>	NaOH to pH > 12	<input type="checkbox"/>
CYANIDE <input type="checkbox"/>			<input type="checkbox"/>
Sampled by: _____			
Remarks: _____			

ATTACHMENT B-6

CHAIN-OF-CUSTODY RECORD FORM

(Original is 8.5 x 11")

[illegible]

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ATTACHMENT B-7

CHAIN-OF-CUSTODY SEAL

Signature _____		CUSTODY SEAL _____
Date _____		Date _____
CUSTODY SEAL _____		Signature _____

ATTACHMENT C-3
PACKER TEST REPORT FORM



PAGE OF

TEST NO:

PROJECT NO.:

SUBJECT:

PROJECT: _____
BORING NO.: _____

CASING DEPTH:

CONTRACTOR:

STATIC WATER LEVEL

TEST INTERVAL:

人

CHECKED:

PACKER PRESSURE

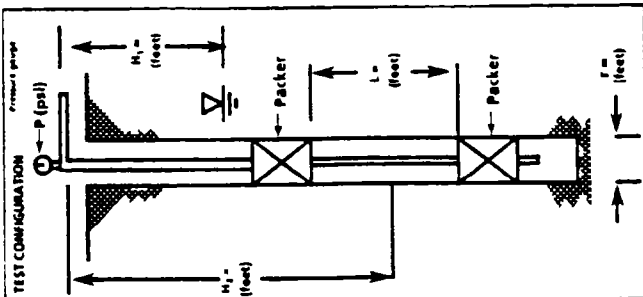
[illegible]

- H_1 is used when the test length is below the water table.
- H_2 is used when the test length is above the water table.

$$CP = (1/(2 \pi L)) \ln(L/r) \quad (70.3155)$$

7.48 Gallons = 1 Ft³
1 py = 2.31 ft head

Remarks:



Length of turbine in water feet	Cp				
	Fr	Re	Re	Re	Re
	(1')	(1.05 × 10 ⁵)	(2.2 × 10 ⁵)	(4.2 × 10 ⁵)	(6.2 × 10 ⁵)
1	31,000	33,500	37,000	43,000	47,000
2	19,000	19,500	19,500	19,500	19,500
3	5,000	5,000	5,000	5,000	5,000
4	5,000	5,000	5,000	5,000	5,000
5	5,000	5,000	5,000	5,000	5,000
6	5,000	5,000	5,000	5,000	5,000
7	5,000	5,000	5,000	5,000	5,000
8	5,000	5,000	5,000	5,000	5,000
9	5,000	5,000	5,000	5,000	5,000
10	5,000	5,000	5,000	5,000	5,000
11	5,000	5,000	5,000	5,000	5,000
12	5,000	5,000	5,000	5,000	5,000
13	5,000	5,000	5,000	5,000	5,000
14	5,000	5,000	5,000	5,000	5,000
15	5,000	5,000	5,000	5,000	5,000
16	5,000	5,000	5,000	5,000	5,000
17	5,000	5,000	5,000	5,000	5,000
18	5,000	5,000	5,000	5,000	5,000
19	5,000	5,000	5,000	5,000	5,000
20	5,000	5,000	5,000	5,000	5,000
21	5,000	5,000	5,000	5,000	5,000
22	5,000	5,000	5,000	5,000	5,000
23	5,000	5,000	5,000	5,000	5,000
24	5,000	5,000	5,000	5,000	5,000
25	5,000	5,000	5,000	5,000	5,000
26	5,000	5,000	5,000	5,000	5,000
27	5,000	5,000	5,000	5,000	5,000
28	5,000	5,000	5,000	5,000	5,000
29	5,000	5,000	5,000	5,000	5,000
30	5,000	5,000	5,000	5,000	5,000
31	5,000	5,000	5,000	5,000	5,000
32	5,000	5,000	5,000	5,000	5,000
33	5,000	5,000	5,000	5,000	5,000
34	5,000	5,000	5,000	5,000	5,000
35	5,000	5,000	5,000	5,000	5,000
36	5,000	5,000	5,000	5,000	5,000
37	5,000	5,000	5,000	5,000	5,000
38	5,000	5,000	5,000	5,000	5,000
39	5,000	5,000	5,000	5,000	5,000
40	5,000	5,000	5,000	5,000	5,000
41	5,000	5,000	5,000	5,000	5,000
42	5,000	5,000	5,000	5,000	5,000
43	5,000	5,000	5,000	5,000	5,000
44	5,000	5,000	5,000	5,000	5,000
45	5,000	5,000	5,000	5,000	5,000
46	5,000	5,000	5,000	5,000	5,000
47	5,000	5,000	5,000	5,000	5,000
48	5,000	5,000	5,000	5,000	5,000
49	5,000	5,000	5,000	5,000	5,000
50	5,000	5,000	5,000	5,000	5,000
51	5,000	5,000	5,000	5,000	5,000
52	5,000	5,000	5,000	5,000	5,000
53	5,000	5,000	5,000	5,000	5,000
54	5,000	5,000	5,000	5,000	5,000
55	5,000	5,000	5,000	5,000	5,000
56	5,000	5,000	5,000	5,000	5,000
57	5,000	5,000	5,000	5,000	5,000
58	5,000	5,000	5,000	5,000	5,000
59	5,000	5,000	5,000	5,000	5,000
60	5,000	5,000	5,000	5,000	5,000
61	5,000	5,000	5,000	5,000	5,000
62	5,000	5,000	5,000	5,000	5,000
63	5,000	5,000	5,000	5,000	5,000
64	5,000	5,000	5,000	5,000	5,000
65	5,000	5,000	5,000	5,000	5,000
66	5,000	5,000	5,000	5,000	5,000
67	5,000	5,000	5,000	5,000	5,000
68	5,000	5,000	5,000	5,000	5,000
69	5,000	5,000	5,000	5,000	5,000
70	5,000	5,000	5,000	5,000	5,000
71	5,000	5,000	5,000	5,000	5,000
72	5,000	5,000	5,000	5,000	5,000
73	5,000	5,000	5,000	5,000	5,000
74	5,000	5,000	5,000	5,000	5,000
75	5,000	5,000	5,000	5,000	5,000
76	5,000	5,000	5,000	5,000	5,000
77	5,000	5,000	5,000	5,000	5,000
78	5,000	5,000	5,000	5,000	5,000
79	5,000	5,000	5,000	5,000	5,000
80	5,000	5,000	5,000	5,000	5,000
81	5,000	5,000	5,000	5,000	5,000
82	5,000	5,000	5,000	5,000	5,000
83	5,000	5,000	5,000	5,000	5,000
84	5,000	5,000	5,000	5,000	5,000
85	5,000	5,000	5,000	5,000	5,000
86	5,000	5,000	5,000	5,000	5,000
87	5,000	5,000	5,000	5,000	5,000
88	5,000	5,000	5,000	5,000	5,000
89	5,000	5,000	5,000	5,000	5,000
90	5,000	5,000	5,000	5,000	5,000
91	5,000	5,000	5,000	5,000	5,000
92	5,000	5,000	5,000	5,000	5,000
93	5,000	5,000	5,000	5,000	5,000
94	5,000	5,000	5,000	5,000	5,000
95	5,000	5,000	5,000	5,000	5,000
96	5,000	5,000	5,000	5,000	5,000
97	5,000	5,000	5,000	5,000	5,000
98	5,000	5,000	5,000	5,000	5,000
99	5,000	5,000	5,000	5,000	5,000
100	5,000	5,000	5,000	5,000	5,000

LEGEND

SOIL TERMS

UNIFIED SOIL CLASSIFICATION (USCS)			
COARSE-GRAINED SOILS More Than Half of Material is Larger Than No. 200 Sieve Size		FINE-GRAINED SOILS More Than Half of Material is Smaller Than No. 200 Sieve Size	
FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)	GROUP SYMBOL	TYPICAL NAMES	TYPICAL NAMES
CLEAN GRAVELS (Low % Fines)	GROUP SYMBOL	TYPICAL NAMES	TYPICAL NAMES
GRAVELS (50%+ >1/4")	GROUP SYMBOL	TYPICAL NAMES	TYPICAL NAMES
SANDS (50%+ <1/4")	GROUP SYMBOL	TYPICAL NAMES	TYPICAL NAMES
Wide range in grain size and intermediate particle sizes.	GW	Well graded gravels, gravel-sand mixtures, little or no fines.	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.
Predominantly one size or a range of sizes with some intermediate sizes missing.	GP	Poorly graded gravels, gravel sand mixtures, little or no fines.	Inorganic clays of low to medium plasticity, silty clay, sandy clays, silty clays, lean clays.
Non-plastic fines (for identification procedures, see ML).	GM	Silty gravels, poorly graded gravel-sand-silt mixtures.	Organic silts and organic silt clays of low plasticity.
Plastic fines (for identification procedures, see CL).	GC	Clayey gravels, poorly graded gravel-sand-silt mixtures.	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
Wide range in grain size and intermediate particle sizes.	SM	Well graded sand, gravelly sands, little or no fines.	Inorganic clays of high plasticity, fat clays.
Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	Poorly graded sand, gravelly sands, little or no fines.	Organic clays of medium to high plasticity.
Non-plastic fines (for identification procedures, see ML).	SM	Silty sands, poorly graded sand-silt mixtures.	Peat and other organic soils
Plastic fines (for identification procedures, see CL).	SC	Clayey sands, poorly graded sand-clay mixtures.	

Boundary classifications, soils possessing characteristics of two groups are designated by combining group symbols. For example, GW GC, well graded gravel-sand mixture with clay binder.

All sieve sizes on this chart are U.S. standard.

LEGEND

SOIL SAMPLES - TYPES

5.2" Split-Barrel Sample

51.3" 0.6. Undisturbed Sample

0 - Other Samples, Specify in Remarks

ROCK TERMS

ROCK HARDNESS (FROM CORE SAMPLES)		ROCK BROKENNESS	
Descriptive Term	Screwdriver or Knife Effects	Descriptive Term	Spacing
Soft	Crushes when pressed with hammer	Very Broken	0.2"
Medium Soft	Can be gouged	Broken	2" - 1"
Medium Hard	Can be scratched	Blocky	1' - 3"
Hard	Cannot be scratched	Massive	3' - 10"

CONSISTENCY OF COHESIVE SOILS


Consistency	UNE COMPRESSIVE STRENGTH (TONS/SQ. FT.)	STANDARD PENETRATION RESISTANCE (BLOWS/FOOT)	FIELD IDENTIFICATION METHODS
Very Soft	Less than 0.25	0 to 2	Easily penetrated several inches by fist
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb.
Medium Stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb.
Stiff	1.0 to 2.0	8 to 15	Readily indented by thumb.
Very Stiff	2.0 to 4.0	15 to 30	Readily indented by thumbnail.
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail.

WATER LEVELS

DATE	WATER LEVEL	INITIAL LEVEL w/DATE & DEPTH
12/18	12/18	12.6'
		12/18
		12.6'

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**ATTACHMENT C-5
EXAMPLE OVERBURDEN MONITORING WELL SHEET**

		BORING NO.: _____
OVERBURDEN MONITORING WELL SHEET		
PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING _____
ELEVATION _____	DATE _____	METHOD _____
FIELD GEOLOGIST _____		DEVELOPMENT _____
		METHOD _____

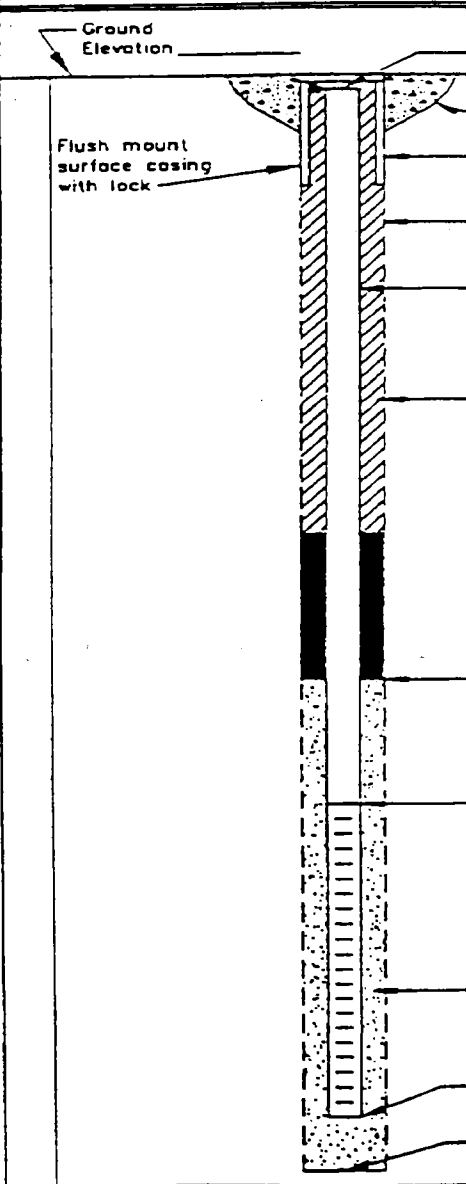
	ELEVATION OF TOP OF SURFACE CASING : _____
	ELEVATION OF TOP OF RISER PIPE: _____
	STICK - UP TOP OF SURFACE CASING: _____
	STICK - UP RISER PIPE : _____
	TYPE OF SURFACE SEAL: _____
	I.D. OF SURFACE CASING: _____
	TYPE OF SURFACE CASING: _____
	RISER PIPE I.D. _____
	TYPE OF RISER PIPE: _____
	BOREHOLE DIAMETER: _____
	TYPE OF BACKFILL: _____
	ELEVATION / DEPTH TOP OF SEAL: _____ / _____
	TYPE OF SEAL: _____
	DEPTH TOP OF SAND PACK: _____
	ELEVATION / DEPTH TOP OF SCREEN: _____ / _____
TYPE OF SCREEN: _____	
SLOT SIZE x LENGTH: _____	
I.D. OF SCREEN: _____	
TYPE OF SAND PACK: _____	
ELEVATION / DEPTH BOTTOM OF SCREEN: _____ / _____	
ELEVATION / DEPTH BOTTOM OF SAND PACK: _____ / _____	
TYPE OF BACKFILL BELOW OBSERVATION WELL: _____	
ELEVATION / DEPTH OF HOLE: _____ / _____	

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**ATTACHMENT C-5A
EXAMPLE OVERBURDEN MONITORING WELL SHEET (FLUSHMOUNT)**

		BORING NO.: _____
<h2 style="margin: 0;">MONITORING WELL SHEET</h2>		

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING _____
ELEVATION _____	DATE _____	METHOD _____
FIELD GEOLOGIST _____		DEVELOPMENT _____
		METHOD _____



ELEVATION TOP OF RISER: _____

TYPE OF SURFACE SEAL: _____

TYPE OF PROTECTIVE CASING: _____

I.D. OF PROTECTIVE CASING: _____

DIAMETER OF HOLE: _____

TYPE OF RISER PIPE: _____

RISER PIPE I.D.: _____

TYPE OF BACKFILL/SEAL: _____

DEPTH/ELEVATION TOP OF SAND: _____

DEPTH/ELEVATION TOP OF SCREEN: _____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK: _____

DEPTH/ELEVATION BOTTOM OF SCREEN: _____

DEPTH/ELEVATION BOTTOM OF SAND: _____

DEPTH/ELEVATION BOTTOM OF HOLE: _____

BACKFILL MATERIAL BELOW SAND: _____

NOTE: SEE VARIOUS VIEWS FOR DETAILS

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ATTACHMENT C-6
EXAMPLE CONFINING LAYER MONITORING WELL SHEET

BORING NO.: _____



**CONFINING LAYER
MONITORING WELL SHEET**

PROJECT _____
 PROJECT NO. _____
 ELEVATION _____
 FIELD GEOLOGIST _____


LOCATION _____
 BORING _____
 DATE _____

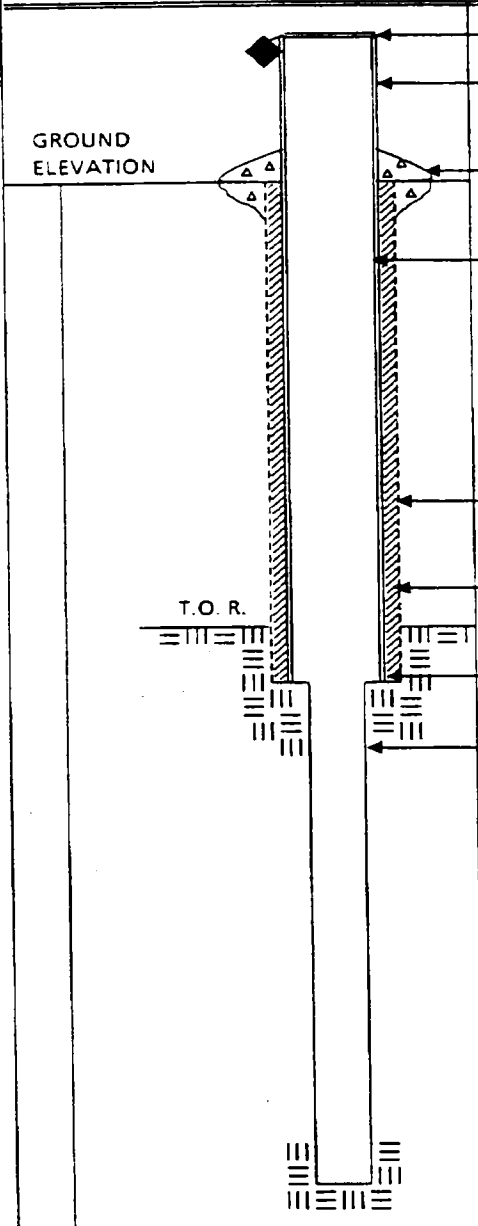
DRILLER _____
 DRILLING _____
 METHOD _____
 DEVELOPMENT _____
 METHOD _____

	ELEVATION OF TOP OF SURFACE CASING :	_____
	ELEVATION OF TOP OF RISER PIPE:	_____
	ELEVATION TOP OF PERM. CASING:	_____
	TYPE OF SURFACE SEAL: _____	
	I.D. OF SURFACE CASING: _____	
	TYPE OF SURFACE CASING: _____	
	RISER PIPE I.D. _____	
	TYPE OF RISER PIPE: _____	
	BOREHOLE DIAMETER: _____	
	PERM. CASING I.D. _____	
	TYPE OF CASING & BACKFILL: _____	
	ELEVATION / DEPTH TOP CONFINING LAYER: _____	
	ELEVATION / DEPTH BOTTOM OF CASING: _____	
	ELEVATION / DEPTH BOT. CONFINING LAYER: _____	
	BOREHOLE DIA. BELOW CASING: _____	
TYPE OF BACKFILL: _____		
ELEVATION / DEPTH TOP OF SEAL: _____		
TYPE OF SEAL: _____		
DEPTH TOP OF SAND PACK: _____		
ELEVATION/DEPTH TOP OF SCREEN: _____		
TYPE OF SCREEN: _____		
TYPE OF SAND PACK: _____		
ELEVATION / DEPTH BOTTOM OF SCREEN: _____		
ELEVATION / DEPTH BOTTOM OF SAND PACK: _____		
TYPE OF BACKFILL BELOW OBSERVATION WELL: _____		
ELEVATION / DEPTH OF HOLE: _____		

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**ATTACHMENT C-7
EXAMPLE BEDROCK MONITORING WELL SHEET - OPEN HOLE WELL**

		BORING NO.: _____	
BEDROCK MONITORING WELL SHEET OPEN HOLE WELL			
PROJECT _____		LOCATION _____	
PROJECT NO. _____		BORING _____	
ELEVATION _____		DATE _____	
FIELD GEOLOGIST _____		DRILLER _____	
		DRILLING _____	
		METHOD _____	
		DEVELOPMENT _____	
		METHOD _____	



ELEVATION OF TOP OF CASING: _____

STICK UP OF CASING ABOVE GROUND SURFACE: _____

TYPE OF SURFACE SEAL: _____

I.D. OF CASING: _____

TYPE OF CASING: _____

TEMP. / PERM.: _____

DIAMETER OF HOLE: _____

TYPE OF CASING SEAL: _____

DEPTH TO TOP OF ROCK: _____

DEPTH TO BOTTOM CASING: _____

DIAMETER OF HOLE IN BEDROCK: _____


DESCRIBE IF CORE / REAMED WITH BIT:

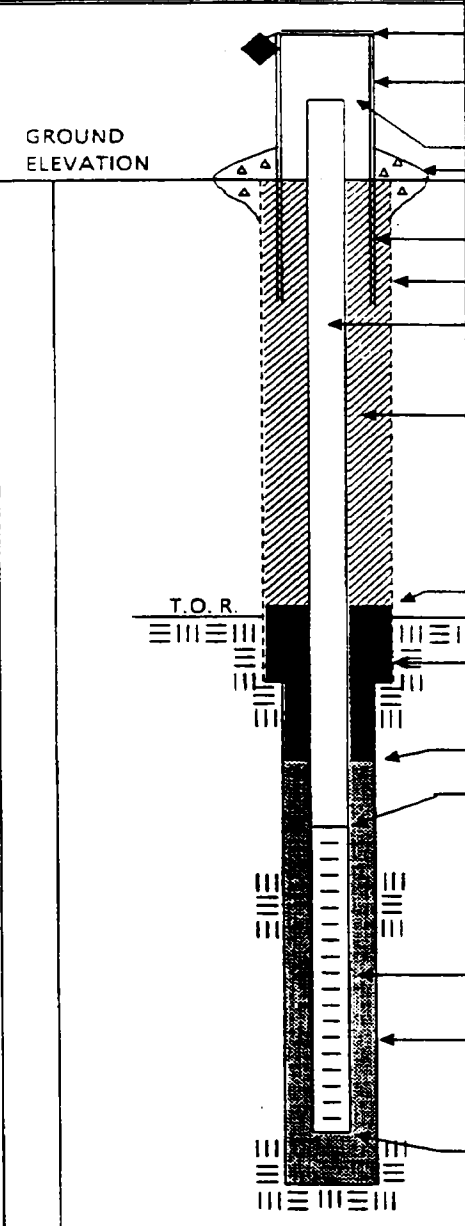
DESCRIBE JOINTS IN BEDROCK AND DEPTH:

ELEVATION / DEPTH OF HOLE: _____

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ATTACHMENT C-8
EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK

		BORING NO.: _____	
BEDROCK MONITORING WELL SHEET WELL INSTALLED IN BEDROCK			
PROJECT _____		LOCATION _____	
PROJECT NO. _____		BORING _____	
ELEVATION _____		DATE _____	
FIELD GEOLOGIST _____		DRILLER _____	
		DRILLING _____	
		METHOD _____	
		DEVELOPMENT _____	
		METHOD _____	

	ELEVATION OF TOP OF SURFACE CASING: _____
	STICK UP OF CASING ABOVE GROUND SURFACE: _____
	ELEVATION TOP OF RISER: _____
	TYPE OF SURFACE SEAL: _____
	I.D. OF SURFACE CASING: _____
	DIAMETER OF HOLE: _____
	RISER PIPE I.D.: _____
	TYPE OF RISER PIPE: _____
	TYPE OF BACKFILL: _____

	ELEVATION / DEPTH TOP OF SEAL: _____
	ELEVATION / DEPTH TOP OF BEDROCK: _____
	TYPE OF SEAL: _____


ELEVATION / DEPTH TOP OF SAND: _____	
ELEVATION / DEPTH TOP OF SCREEN: _____	
TYPE OF SCREEN: _____	
SLOT SIZE x LENGTH: _____	
I.D. SCREEN: _____	
TYPE OF SAND PACK: _____	

DIAMETER OF HOLE IN BEDROCK: _____	
CORE / REAM: _____	

ELEVATION / DEPTH BOTTOM SCREEN: _____	
ELEVATION / DEPTH BOTTOM OF HOLE: _____	

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**ATTACHMENT C-8A
EXAMPLE BEDROCK MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK (FLUSHMOUNT)**

		BEDROCK MONITORING WELL SHEET WELL INSTALLED IN BEDROCK		BORING NO.: _____
PROJECT: _____		LOCATION: _____		DRILLER: _____
PROJECT NO.: _____		BORING: _____		DRILLING METHOD: _____
ELEVATION: _____		DATE: _____		DEVELOPMENT METHOD: _____
FIELD GEOLOGIST: _____				

	ELEVATION TOP OF RISER: _____
	TYPE OF SURFACE SEAL: _____
	TYPE OF PROTECTIVE CASING: _____
	I.D. OF PROTECTIVE CASING: _____
	DIAMETER OF HOLE: _____
	TYPE OF RISER PIPE: _____
	RISER PIPE I.D.: _____
	TYPE OF BACKFILL/SEAL: _____
	DEPTH/ELEVATION TOP OF BEDROCK: _____
	DEPTH/ELEVATION TOP OF SAND: _____
	DEPTH/ELEVATION TOP OF SCREEN: _____
	TYPE OF SCREEN: _____
	SLOT SIZE x LENGTH: _____
	TYPE OF SAND PACK: _____
	DIAMETER OF HOLE IN BEDROCK: _____
DEPTH/ELEVATION BOTTOM OF SCREEN: _____	
DEPTH/ELEVATION BOTTOM OF SAND: _____	
DEPTH/ELEVATION BOTTOM OF HOLE: _____	
BACKFILL MATERIAL BELOW SAND: _____	

ADFILE: 1670\GEOL\WDRY1.DWG

ATTACHMENT D
EXAMPLE EQUIPMENT CALIBRATION LOG

[illegible]

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**ATTACHMENT F
FIELD TRIP SUMMARY REPORT
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SUNDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

MONDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

TUESDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

WEDNESDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

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**ATTACHMENT F
PAGE 2 OF 2
FIELD TRIP SUMMARY REPORT**

THURSDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

FRIDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

SATURDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____



BROWN & ROOT ENVIRONMENTAL

STANDARD OPERATING PROCEDURES

Number
SA-7.1

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1 of 9

Effective Date
03/01/96

Revision
0

Applicability
B&R Environmental, NE

Prepared
Earth Sciences Department

Subject DECONTAMINATION OF FIELD EQUIPMENT
AND WASTE HANDLING

Approved
D. Senovich

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1.0 PURPOSE

The purpose of this procedure is to provide guidelines regarding the appropriate procedures to be followed when decontaminating drilling equipment, monitoring well materials, chemical sampling equipment and field analytical equipment.

2.0 SCOPE

This procedure addresses drilling equipment and monitoring well materials decontamination, as well as chemical sampling and field analytical equipment decontamination. This procedure also provides general reference information on the control of contaminated materials.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Project Manager - Responsible for ensuring that all field activities are conducted in accordance with approved project plan(s) requirements.

Field Operations Leader (FOL) - Responsible for the onsite verification that all field activities are performed in compliance with approved Standards Operating Procedures or as otherwise dictated by the approved project plan(s).

5.0 PROCEDURES

To ensure that analytical chemical results reflect actual contaminant concentrations present at sampling locations, the various drilling equipment and chemical sampling and analytical equipment used to acquire the environment sample must be properly decontaminated. Decontamination minimizes the potential for cross-contamination between sampling locations, and the transfer of contamination offsite.

5.1 Drilling Equipment

Prior to the initiation of a drilling program, all drilling equipment involved in field sampling activities shall be decontaminated by steam cleaning at a predetermined area. The steam cleaning procedure shall be performed using a high-pressure spray of heated potable water producing a pressurized stream of steam. This steam shall be sprayed directly onto all surfaces of the various equipment which might contact environmental samples. The decontamination procedure shall be performed until all equipment is free of all visible potential contamination (dirt, grease, oil, noticeable odors, etc.) In addition, this decontamination procedure shall be performed at the completion of each sampling and/or drilling location, including soil borings, installation of monitoring wells, test pits, etc. Such equipment shall include drilling rigs, backhoes, downhole tools, augers, well casings, and screens. Where the drilling rig is set to perform multiple borings at a single area of concern, the steam-cleaning of the drilling rig itself may be waived with proper approval. Downhole equipment, however, must always be steam-cleaned between borings. Where PVC well casings are to be installed, decontamination is not required if the manufacturer provides these casings in factory-sealed, protective, plastic sleeves (so long as the protective packaging is not compromised until immediately before use).

The steam cleaning area shall be designed to contain decontamination wastes and waste waters and can be a lined excavated pit or a bermed concrete or asphalt pad. For the latter, a floor drain must be

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provided which is connected to a holding facility. A shallow above-ground tank may be used or a pumping system with discharge to a waste tank may be installed.

In certain cases such an elaborate decontamination pad is not possible. In such cases, a plastic lined gravel bed pad with a collection system may serve as an adequate decontamination area. Alternately, a lined sloped pad with a collection pump installed at the lower end may be permissible. The location of the steam cleaning area shall be onsite in order to minimize potential impacts at certain sites.

Guidance to be used when decontaminating drilling equipment shall include:

- As a general rule, any part of the drilling rig which extends over the borehole, shall be steam cleaned.
- All drilling rods, augers, and any other equipment which will be introduced to the hole shall be steam cleaned.
- The drilling rig, all rods and augers, and any other potentially contaminated equipment shall be decontaminated between each well location to prevent cross contamination of potential hazardous substances.

Prior to leaving at the end of each work day and/or at the completion of the drilling program, drilling rigs and transport vehicles used onsite for personnel or equipment transfer shall be steam cleaned, as practicable. A drilling rig left at the drilling location does not need to be steam cleaned until it is finished drilling at that location.

5.2 Sampling Equipment

5.2.1 Bailers and Bailing Line

The potential for cross-contamination between sampling points through the use of a common bailer or its attached line is high unless strict procedures for decontamination are followed. For this reason, it is preferable to dedicate an individual bailer and its line to each sample point, although this does not eliminate the need for decontamination of dedicated bailers. For non-dedicated sampling equipment, the following conditions and/or decontamination procedures must be followed.

Before the initial sampling and after each successive sampling point, the bailer must be decontaminated. The following steps are to be performed when sampling for organic contaminants. Note: contract-specific requirements may permit alternative procedures.

- Potable water rinse
- Alconox or Liquinox detergent wash
- Scrubbing of the line and bailer with a scrub brush (may be required if the sample point is heavily contaminated with heavy or extremely viscous compounds)
- Potable water rinse
- Rinse with 10 percent nitric acid solution*
- Deionized water rinse

* Due to the leaching ability of nitric acid on stainless steel, this step is to be omitted if a stainless steel sampling device is being used and metals analysis is required with detection limits less than approximately 50 ppb.

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- Acetone or methanol rinse (in some EPA Regions, isopropanol is used instead)
- Hexane rinse**
- Copious distilled/Deionized water rinse
- Air dry

If sampling for volatile organic compounds (VOCs) only, the nitric acid, acetone, methanol, and hexane rinses may be omitted. Only reagent grade or purer solvents are to be used for decontamination. When isopropanol is used, the bailer must be thoroughly dry before using to acquire the next sample.

In general, specially purchased pre-cleaned disposable sampling equipment is not decontaminated (nor is an equipment rinsate blank collected) so long as the supplier has provided certification of cleanliness. If decontamination is performed on several bailers at once (i.e., in batches), bailers not immediately used may be completely wrapped in aluminum foil (shiny-side toward equipment) and stored for future use. When batch decontamination is performed, one equipment rinsate is generally collected from one of the bailers belonging to the batch before it is used for sampling.

It is recommended that clean, dedicated braided nylon or polypropylene line be employed with each bailer use.

5.2.2 Sampling Pumps

Most sampling pumps are low volume (less than 2 gpm) pumps. These include peristaltic, diaphragm, air-lift, pitcher and bladder pumps, to name a few. If these pumps are used for sampling from more than one sampling point, they must be decontaminated prior to initial use and after each use.

The procedures to be used for decontamination of sampling pumps compare to those used for a bailer except that the 10 percent nitric acid solution is omitted. Each of the liquid factions is to be pumped through the system. The amount of pumping is dependent upon the size of the pump and the length of the intake and discharge hoses. Certain types of pumps are unacceptable for sampling purposes. For peristaltic pumps, the tubing is replaced rather than cleaned.

An additional problem is introduced when the pump relies on absorption of water via an inlet or outlet hose. For organic sampling, this hose should be Teflon. Other types of hoses leach organics (especially phthalate esters) into the water being sampled or adsorb organics from the sampled water. For all other sampling, the hose should be Viton, polyethylene, or polyvinyl chloride (listed in order of preference). Whenever possible, dedicated hoses should be used. It is preferable that these types of pumps not be used for sampling, only for purging.

5.2.3 Filtering Equipment

On occasion, the sampling plan may require acquisition of filtered groundwater samples. Field-filtering is addressed in SOP SA-6.1 and should be conducted as soon after sample acquisition as possible. To this end, three basic filtration systems are most commonly used: the in-line disposable Teflon filter, the inert gas over-pressure filtration system, and the vacuum filtration system.

For the in-line filter, decontamination is not required since the filter cartridge is disposable, however, the cartridge must be disposed of in an approved receptacle and the intake and discharge lines must still be decontaminated or replaced before each use.

** If sampling for pesticides, PCBs, or fuels.

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For the over-pressure and the vacuum filtration systems, the portions of the apparatus which come in contact with the sample must be decontaminated as outlined in the paragraphs describing the decontamination of bailers. (Note: Varieties of both of these systems come equipped from the manufacturer with Teflon-lined surfaces for those that would come into contact with the sample. These filtration systems are preferred when decontamination procedures must be employed.)

5.2.4 Other Sampling Equipment

Field tools such as trowels and mixing bowls are to be decontaminated in the same manner as described above.

5.3 Field Analytical Equipment

5.3.1 Water Level Indicators

Water level indicators that come into contact with groundwater must be decontaminated using the following steps:

- Rinse with potable water
- Rinse with deionized water
- Acetone or methanol rinse (unless otherwise directed by manufacturer)
- Rinse with deionized water

Water level indicators that do not come in contact with the groundwater but may encounter incidental contact during installation or retrieval need only undergo the first and last steps stated above.

5.3.2 Probes

Probes (e.g., pH or specific-ion electrodes, geophysical probes, or thermometers) which would come in direct contact with the sample, will be decontaminated using the procedures specified above unless manufacturer's instructions indicate otherwise (e.g., dissolved oxygen probes). Probes that contact a volume of groundwater not used for laboratory analyses can be rinsed with deionized water. For probes which make no direct contact, (e.g., OVA equipment) the probe is self-cleaning when exposure to uncontaminated air is allowed and the housing can be wiped clean with paper-towels or cloth wetted with alcohol.

5.4 Waste Handling

For the purposes of these procedures, contaminated materials are defined as any byproducts of field activities that are suspected or known to be contaminated with hazardous substances. These byproducts include such materials as decontamination solutions, disposable equipment, drilling muds, well-development fluids, and spill-contaminated materials and Personal Protection Equipment (PPE).

The procedures for obtaining permits for investigations of sites containing hazardous substances are not clearly defined at present. In the absence of a clear directive to the contrary by the EPA and the states, it must be assumed that hazardous wastes generated during field activities will require compliance with Federal agency requirements for generation, storage, transportation, or disposal. In addition, there may be state regulations that govern the disposal action. This procedure exclusively describes the technical methods used to control contaminated materials.

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The plan documents for site activities must include a description of control procedures for contaminated materials. This planning strategy must assess the type of contamination, estimate the amounts that would be produced, describe containment equipment and procedures, and delineate storage or disposal methods. As a general policy, it is wise to select investigation methods that minimize the generation of contaminated spoils. Handling and disposing of potentially hazardous materials can be dangerous and expensive. Until sample analysis is complete, it is assumed that all produced materials are suspected of contamination from hazardous chemicals and require containment.

5.5 Sources of Contaminated Materials and Containment Methods

5.5.1 Decontamination Solutions

All waste decontamination solutions and rinses must be assumed to contain the hazardous chemicals associated with the site unless there are analytical or other data to the contrary. The waste solution volumes could vary from a few gallons to several hundred gallons in cases where large equipment required cleaning.

Containerized waste rinse solutions are best stored in 55-gallon drums (or equivalent containers) that can be sealed until ultimate disposal at an approved facility. Larger equipment such as backhoes and tractors must be decontaminated in an area provided with an impermeable liner and a liquid collection system. A decontamination area for large equipment could consist of a bermed concrete pad with a floor drain leading to a buried holding tank.

5.5.2 Disposable Equipment

Disposable equipment that could become contaminated during use typically includes PPE, rubber gloves, boots, broken sample containers, and cleaning-wipes. These items are small and can easily be contained in 55-gallon drums with lids. These containers should be closed at the end of each work day and upon project completion to provide secure containment until disposed.

5.5.3 Drilling Muds and Well-Development Fluids

Drilling muds and well-development fluids are materials that may be used in groundwater monitoring well installations. Their proper use could result in the surface accumulation of contaminated liquids and muds that require containment. The volumes of drilling muds and well-development fluids used depend on well diameter and depth, groundwater characteristics, and geologic formations. There are no simple mathematical formulas available for accurately predicting these volumes. It is best to rely on the experience of reputable well drillers familiar with local conditions and the well installation techniques selected. These individuals should be able to estimate the sizes (or number) of containment structures required. Since guesswork is involved, it is recommended that an slight excess of the estimated amount of containers required will be available.

Drilling muds are mixed and stored in what is commonly referred to as a mud pit. This mud pit consists of a suction section from which drilling mud is withdrawn and pumped through hoses, down the drill pipe to the bit, and back up the hole to the settling section of the mud pit. In the settling section, the mud's velocity is reduced by a screen and several flow-restriction devices, thereby allowing the well cuttings to settle out of the mud/fluid.

The mud pit may be either portable above-ground tanks commonly made of steel (which is preferred) or stationary in-ground pits as depicted in Attachment A. The above-ground tanks have a major advantage over the in-ground pits because the above-ground tanks isolate the natural soils from the

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contaminated fluids within the drilling system. These tanks are also portable and can usually be cleaned easily.

As the well is drilled, the cuttings that accumulate in the settling section must be removed. This is best done by shoveling them into drums or other similar containers. When the drilling is complete, the contents of the above-ground tank are likewise shoveled or pumped into drums, and the tank is cleaned and made available for its next use.

If in-ground pits are used, they should not extend into the natural water table. They should also be lined with a bentonite-cement mixture followed by a layer of flexible impermeable material such as plastic sheeting. Of course, to maintain its impermeable seal, the lining material used would have to be nonreactive with the wastes. An advantage of the in-ground pits is that well cuttings do not necessarily have to be removed periodically during drilling because the pit can be made deep enough to contain them. Depending on site conditions, the in-ground pit may have to be totally excavated and refilled with uncontaminated natural soils when the drilling operation is complete.

When the above-ground tank or the in-ground pit is used, a reserve tank or pit should be located at the site as a backup system for leaks, spills, and overflows. In either case, surface drainage should be such that any excess fluid could be controlled within the immediate area of the drill site.

The containment procedure for well-development fluids is similar to that for drilling muds. The volume and weight of contaminated fluid will be determined by the method used for development. When a new well is pumped or bailed to produce clear water, substantially less volume and weight of fluid result than when backwashing or high-velocity jetting is used.

5.5.4 Spill-Contaminated Materials

A spill is always possible when containers of liquids are opened or moved. Contaminated sorbents and soils resulting from spills must be contained. Small quantities of spill-contaminated materials are usually best contained in drums, while larger quantities can be placed in lined pits or in other impermeable structures. In some cases, onsite containment may not be feasible and immediate transport to an approved disposal site will be required.

5.6 Disposal of Contaminated Materials

Actual disposal techniques for contaminated materials are the same as those for any hazardous substance, that is, incineration, landfilling, treatment, and so on. The problem centers around the assignment of responsibility for disposal. The responsibility must be determined and agreed upon by all involved parties before the field work starts. If the site owner or manager was involved in activities that precipitated the investigation, it seems reasonable to encourage his acceptance of the disposal obligation. In instances where a responsible party cannot be identified, this responsibility may fall on the public agency or private organization investigating the site.

Another consideration in selecting disposal methods for contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of a suitable onsite disposal structure is expected, contaminated materials generated during the investigation should be stored at the site for disposal with other site materials. In this case, the initial containment structures should be evaluated for use as long-term storage structures. Also, other site conditions such as drainage control, security, and soil type must be considered so that proper storage is provided. If onsite storage is expected, then the containment structures should be specifically designed for that purpose.

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6.0 REFERENCES

Brown & Root Environmental: Standard Operating Procedure No. 4.33, Control of Contaminated Material.

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ATTACHMENT A

TWO TYPES OF MUD PITS USED IN WELL DRILLING

